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EDITORIAL.

ITEMS AND NOVELTIES.

Sir William Fairbairn, F. R. S.—We take the following obituary notice of this celebrated English Engineer from the *Journal of the Society of Arts*, of which Society he was for thirty years an active member, and at one time Vice-President:

"Sir William Fairbairn died on Tuesday, the 18th day of August last, in his 83d year, at Farnham, Surrey. He was the son of Mr. Andrew Fairbairn of Smailholm. He was born at Kelso in Roxburghshire in the early part of the year 1789, and received his education as a boy at a small school at Mullochy, in Rosshire, subsequently acquiring his professional training at Newcastle-on-Tyne. He settled in Manchester in 1817, in partnership with Mr. Lillie, in conjunction with whom his name rose to become that of one of the leading firms among the machine makers of that city. Mr. Fairbairn acted in conjunction with Robert Stephenson in the planning and execution of the celebrated Britannia and Conway Tubular railway bridge across the Menai Straits. In 1850, he published in the Philosophical Transactions of the Royal Society his 'Experimental Inquiry into the strength of wrought iron plates and their riveted joints, as applied to shipbuilding and to vessels exposed to severe strains.' To him also we

owe many useful researches into the causes of the explosions of steam boilers. He was a Fellow of the Royal Society, a corresponding member of the French Institute, an active or honorary member of almost every Society connected with engineering science in this country, and of many philosophical societies; and had received medals or other marks of recognition for his services to science from most of the crowned heads of Europe. He was one of Her Majesty's Commissioners for the Great Exhibition of 1851, and again took an active part in the organization of the second Great Exhibition in 1862, in the same capacity. He was also a member of the Jury of the Mechanical Department of the Great Exhibition of 1851, and acted as President of the Jury of the corresponding section of the Exhibition of Industry at Paris in 1855. In 1861, he occupied the position of President of the British Association for the advancement of Science. He was created a Baronet at the recommendation of Mr. Gladstone in 1869. The greater part of Sir William Fairbairn's acknowledged publications appeared in the Philosophical Transactions of the Royal Society, in the Reports of the British Association, and in the Transactions of the Philosophical Society of Manchester, in which he filled the chair of Dalton. Some of his works, however, were also published separately. Among his chief productions may be specified treatises on 'Canal Navigation,' on 'The Strength and other Properties of Hot and Cold Blast Iron,' on 'The Strength of Locomotive Boilers,' on 'The Strength of Iron at Different Temperatures,' on 'The Effect of Repeated Melting upon the Strength of Cast Iron,' on 'The Irons of Great Britain,' on 'The Strength of Iron Plates and Riveted Joints,' on 'The Application of Iron to Building purposes in general,' on 'Useful Information for Engineers,' etc."

Melting of the Metal for the New Metric Standards of the International Metric Commission at Paris.—At the meeting of the Executive Committee of the International Metric Commission in October last, the fusion of the large single ingot of platinum-iridium, weighing 250 kilograms, out of which all the new metric standards were to be constructed, was fixed for the end of the following April, but the completion of the operation was delayed by accidental circumstances until the middle of the following month. As this was the first occasion on which any attempt had ever been made to melt together more than a few kilograms of platinum or of platinum alloyed with iridium, it was necessary to make a great

number of experimental meltings during the intermediate time in order to secure success in the great operation.

All the actual meltings of the platinum and iridium have been made at the Conservatoire des Arts et Metiers, in a building erected for the purpose. The work has been carried out under the superintendence of M. Tresca, the Sous-Directeur of the Conservatoire, who is also honorary secretary of the Commission, and more immediately intrusted with the technical operations of constructing the new standards. He has had the advantage of the cordial assistance of Mr. George Matthey, of the firm of Johnson and Matthey, Hatton Garden, from whom the large mass of platinum and iridium was obtained. Mr. G. Matthey has had large personal experience in melting platinum, and he remained at Paris from the beginning of April assisting in the work.

It was necessary that the whole of the platinum and iridium should be separately assayed and purified previously to their being melted together. This process was entrusted to M. Henri Sainte-Claire Deville, and carried out at the Ecole Normale, of which he is director. The greatest difficulty in the purification consisted in getting rid of the osmium, which is found in the natural ore in combination with platinum and with iridium. But the chemical difficulty was satisfactorily overcome by M. Deville after many experiments made by him.

The whole of the platinum and iridium had thus been ascertained to be perfectly pure when delivered to M. Tresca for melting. The first process was to melt portions of the pure platinum, its melting point being about 1,900° C., and considerably lower than that of iridium, which is about 2,400° C. Portions of the platinum were then remelted together with iridium, in the proportions fixed upon of 90 per cent. of platinum and 10 per cent. of iridium. Quantities of from 10 to 15 kilograms of platinum-iridium were, in the first instance, melted together. Several of these smaller ingots were then remelted into larger ingots of rather more than 80 kilograms each, and the final operation was to remelt three of these larger ingots into a single ingot of 250 kilograms.

Each of the meltings was made as nearly as possible of uniform form in a furnace heated with oxy-hydrogen gas. The furnace was made of a block of the ordinary sandy limestone used for buildings in Paris. For the smaller ingots a square block of stone was employed with a hemispherical cavity about 6 in. (15 centimeters) in diameter, for containing the metal. This small block had a cover of

similar form, and through its middle was a vertical hole, about ¼ in. in diameter, in which the tube for conveying the gas was fixed with mortar. When the metal was placed in the furnace, and the jet of lighted gas directed upon it, sufficient mortar was placed on the joining of the upper and lower blocks of stone to make it air-tight. For the three larger ingots a long oblong furnace was used, with a cavity of the same breadth, but a little deeper and much longer, and three gas-tubes were used. The largest furnace required for the whole quantity of metal had six gas-tubes, each about one inch in diameter, inserted in the upper block. The ordinary illuminating gas was used, mixed with the requisite proportion of oxygen gas, made on the premises and stored in a large gasometer placed near the furnace-room. For obtaining a sufficient blast the power of a 15-horse steam-engine was employed.

In order to facilitate the melting, it was necessary first to divide the larger ingots into small pieces. About half the quantity for a single melting, thus divided into small lumps, was placed in the mould, and when this was completely melted the remainder, which had been drawn out into long thin bars, was introduced gradually through two small holes opposite each other in the furnace. These holes also enabled the interior of the furnace to be seen, together with the progress of the melting, and they could be closed by stone plugs when requisite. The division of the ingots was a difficult operation, as this alloy of platinum and iridium is harder than ordinary steel. A V cut, about ⅛ in. deep, was made around the ingot with a cold chisel, though not without splintering the edges of a considerable number of the best tempered chisels. The ingot was then placed under a hydraulic press, supported upon the rounded tops of two strong iron bars, a sufficient distance apart. The rounded part of a third bar was placed upon the ingot, in the line of the cut, and the power of the press being applied, the ingot was broken in half, presenting in every instance a regular crystallized grain.

The melted metal was not cast into a separate mould, but was allowed to cool in the furnace. During the melting a portion of the interior of the stone, to the depth of about half an inch, became calcined by the excessive heat and formed into lime in a powdery state, which floated on the surface of the melted metal. When the metal was sufficiently cool, the stone mould was broken and the ingot removed to a bath of hydrochloric acid, which dissolved every portion

of lime or other foreign matter upon the surface of the ingot, but does not act upon platinum-iridium. The ingot was then left quite clean and pure.

The first of the larger ingots of 80 kilograms was successfully melted on April 25. The second was melted on May 1, when Marshal MacMahon, the President of the Republic, accompanied by M. Deseilligny, the Minister of Commerce, were present unofficially, and remained during the whole process, appearing to take great interest in the operations. The third of the larger ingots was melted on May 7.

The melting of the great ingot of 250 kilograms took place on May 13th, in presence of nearly every member of the French Section of the Commission, of M. Struve from St. Petersburg, MM. Stas and Heusschen from Brussels, M. Bosscha from Holland, Prof. Miller and Mr. Chisholm, delegates from Great Britain, and other foreign commissioners. It was successfully accomplished with the greatest facility and regularity, and without the slightest hitch or accident.

The dimensions of the cavity in the furnace, and consequently of the large ingots produced, were as follows:—

	Meter	Inch
Length	1·24, or about	44·9
Breadth	0·15, "	5·9
Depth	0·07, "	2·8
Thickness of stone above the cavity	0·15 "	5·9

The time occupied in the process was as follows:—

2.10 P.M.—Furnace lighted and heated by degrees.
2.24 " —Furnace thoroughly heated.
3. 4 " —Contents of metal (130 kilograms) melted and bars begun to be introduced.
3.27 " —All the metal melted.
4.15 " —Metal entirely solid, but still at white heat; lid lifted.

In about half an hour the mould was broken and the ingot removed to the hydrochloric bath. When taken out it was examined, and found, to all appearances, perfect.

The stone used is so remarkably slow a conductor of heat, that when the whole mass of metal was in a melted state the upper surface of the stone was hardly warm, as was tested by the hands of several of the persons present being placed upon it.

Portions of the three large ingots had been previously tested and found to be very nearly indeed of pure platinum and pure iridium in the proportions of 9 to 1. The large ingot will also be assayed, and, if deemed necessary, again melted, in order that the requisite homogeneity may be attained.

The work of constructing all the new line-standard meters from this single ingot will at once be proceeded with, and there will be sufficient surplus metal for making first all the new standard kilograms, and then such number of end-standard meters as may be required.—*Nature*

Hydraulic Brakes.—We find in the *English Mechanic*, the following abstract of a paper upon the above subject, read by F. H. Varley and E. Furness, at the recent meeting of the British Association at Belfast:

In arresting a heavy body in motion, it is necessary to exert a force equal to the dynamic effect of the weight of the body, multiplied by the square of its velocity. Should this be effected instantaneously, a great concussion is the result, such being the effect experienced when a piece of machinery in rapid rotation is suddenly arrested by clogging, causing the teeth of the wheels to be stripped off, or the shafts broken or distorted, which frequently occurs with iron rolling mills, sugar-cane crushing mills, and not unfrequently causing the breaking of the screw shafts of steam vessels, and all classes of machinery subject to rapidly varying strains.

To reduce these enormous strains to within the working strength of the material of which the machinery is constructed, it is necessary to spread the force of the concussion over a portion of a revolution or revolutions, or period of time and so destroy its intensity. Contrivances for effecting this purpose, have hitherto taken the shape of friction brakes or clutches. They, however, are open to the objection that they consume a large amount of useful power by generating heat and destroying the surfaces by abrasion.

The authors describe a means of attaining a better result by hydraulic pressure, rendered elastic by placing in the fluid elastic substances, such pressure acting against the face of a ram working in a cylinder. To convert the longitudinal motion of the ram into the rotary motion of the shaft, they employ the following arrangement:—The wheel which communicates the power to the machinery is bored to fit freely on a shaft, and has a boss with its face on the inner side shaped of a spiral incline or screw form, and which is made to bear against an

annular plunger, the outer end of which is shaped to the counterpart screw form. The hole in the plunger is bored to the same size as the wheel, and works in a cylinder fitted concentrically on the shaft which passes through the hole of the ram and wheel, the ram being made water-tight, by suitable packings, or leathers, both with the shaft and the cylinder. The outer end, or mouth of the cylinder has slots or recesses cut into it longitudinally, in which lugs or projections on the ram work, so that the ram can slide in and out the cylinder, but cannot turn without the cylinder turns with it. Proper inlets for charging the cylinder with fluid and elastic balls are provided.

If the shaft be revolving and the wheel driving the machine is stopped, the ram is immediately pressed into the cylinder and compresses the elastic material placed in the fluid by the spirally inclined faces rising one upon another. The wheel at the same time, is prevented from moving laterally along the shaft by a fixed collar on the outer side of the wheel; this motion of the ram allows the shaft to continue its rotation while the wheel is held by a sudden shock or stoppage, so that the machinery in such emergencies is gradually pulled up without being smashed to pieces. In crushing mills, through too heavy a feed, the rolls only require to be allowed to slacken in speed to admit of the cane yielding under the pressure, when the obstacle to rapid rotation has passed the rolls. The pressure stored up in the cylinder reacts on the ram, and by the spirally inclined end acting on the counter-form boss of the wheel, quickly brings the rolls to the speed of the driving shaft and thus utilizes the force of the strain.

The Artist's Rotary Color and Brush Stand.—At the meeting of the Institute held on Wednesday evening, September 16th, a stand was exhibited, invented by Mr. Samuel James, and for which a patent has been allowed. It will ultimately take the place of the old and inconvenient color box, as it enable the artist to have his colors, brushes, palette, oils, turpentine and other requisites at his side in a compact and convenient form; thus saving time and annoyance by keeping everything in such order that he can select at a glance from the stand, the color, brush, or whatever else he may wish to use. It is not only useful because of its complete arrangements, but it is also an ornamental object in the studio. The following description of the stand will show its adaptation to the purpose for which it was designed: Upon an ornamental cast iron tripod is affixed an upright wrought

iron stem for supporting, 1st. The Palette holder which is triangular shaped and revolves upon the stem, being held at the proper height by a pin passing through the stem. 2d. A Rack divided into compartments for holding the tubes of colors, space being left above each compartment to allow the artist to mark each compartment with the color in the tube, thereby being enabled to select the color from the tints in the space. The upper part of this rack is arranged to hold bottles for oil, varnish, turpentine and wash cup; this rack also revolves upon the stem. 3d. Resting upon rack 2 and fitting around the stem is a water cup for keeping brushes soft that have not been washed free from paint, the brushes being held in the cup from the brush rack. 4th. A brush rack consisting of a wheel the outer edge of which has concavity sufficient to hold a spiral wire spring, which will adapt itself to hold brushes of any size. 5th. An ornamental cone-shaped top used as a brush receiver, into which the artist may drop his brushes after placing his palette upon its rack. J.

Editorial Correspondence.

[We have received from a gentleman of this city prominent as an Engineer, the following valuable letter upon the use of screw piles as foundations, written to him by Col. Ellers in response to a letter of inquiry. We are sure that the long experience of Col. Ellers in these matters gives to his words a weight of authority which will make the statements in his letter as acceptable to our readers as were his views on the use of nitro-glycerin, published in the September number of this Journal.—Ed.]

On the Use of Screw Piles as Foundations.

My Dear Sir: I fully concur with you as to the non-advisability of using screw piles, or, in fact, piles of any description, in the work in question, and I fail to comprehend how or in what manner their use can be defended either on the ground of durability or that of economy. With a solid rock bottom overlaid with a deposit of soft mud but 5 or 6 feet deep, and with only 6 or 8 feet of water at the site of the proposed work, I do not see wherein stability of structure can be secured or economy attained. Screw piles have been used by European engineers for many years, and that master of constructive

art—Brunel—was, I think, the first to design and use a hollow cast iron cylindrical pile, with an exterior thread or spiral flange on the lower end, whose width varied from 12 to 30 inches, according to the size of the pile and the nature of the material into which it was set or screwed. Solid wrought iron screw piles on the "Mitchell" principle are extensively used abroad in the construction of piers, jetties, and foundation supports of almost every description, and, where uncontrolled by local circumstances, have proved alike, strong, durable and economical. I am not aware that the nature of the water has ever made any difference in their adoption by engineers. They have been used in the construction of one or two lighthouses in this country; and in Europe, Asia, and Australia, their use by English engineers has been quite extensive. Their diameter varies from 4 to 8 inches, and, while the latter dimension (the diameter) does not materially affect the cost of a cast cylindrical pile on the Brunel principle, it becomes a limiting item in the use of solid wrought iron piles, and to such an extent that a diameter much exceeding six inches is rarely used. The spirals or screws used on the Mitchell pile are always of cast iron, and their diameters—from out to out—vary from 2 to 4 feet. The resistance to settlement of a properly proportioned and well made screw pile in good sand or other material equally compact and reliable, and not subject to disturbing influences, is $5\ D^2 = W$, wherein D = the diameter of the screw, from out to out, in feet, and W = the safe load in tons of 2240 lbs. Greater loads than those given by the above formula have been safely used, but experience teaches me that it is not always best to approach too near the dividing line between theory and practice. The setting or screwing process on shore or in water of ordinary depth is extremely simple and economical. A temporary platform, or a raft or float is securely moored at the site of the proposed work—the rigidly fixed platform on timber piles being the best, however, and its area or size is controlled by the number of piles to be driven or screwed, the position and application of the power for driving, and similar local circumstances rendered imperative by the location and character of the work. The iron piles are then accurately adjusted, and kept in place by a few temporary "guide timbers," a timber wheel from 10 to 20 feet in diameter is keyed or fitted to the upper portion of the pile, a rope is passed around the periphery of the wheel and carried to a crab winch, or any similar species of geared hand power conveniently located, and by means of which the wheel and pile are made to revolve, and the latter to enter the material in which it is to remain. Or, the pile may be fitted with an ordinary adjustable capstan head, and the requisite motion secured by hand or animal power in the usual manner in which capstans are worked. But little pressure or weight is required to make the pile enter its place and make its own headway thereafter. The length of a wrought iron pile is manifestly limited by its tensional resistance. the Mitchell pile readily passes through the most compact material,

and will easily displace, in its descent, stones or boulders of moderate size. The spirals or threads generally pass but once, or one and a half times around the lower end of the pile, and their pitch is never very great.

I have no reliable data at hand on which to predicate an opinion as to the real durability of metallic piles. Cast iron supporting members, and, I think, sheet piling, have been used in England for upwards of 50 years, without evidencing any present appearances of decay even at the water line; and solid wrought iron piles show an equally sound and durable condition after an exposure of 16 years. A patent was issued to a Mr. Mosely, some few years ago, for an improvement in cast iron hollow cylindrical piles, open at the lower end, with the usual form of cutting edge, like Mr. Brunel's, or closed with a solid gimlet like screw and point. In specifying the use of the open end piles, the patentee proposed to simply screw them sufficiently deep to secure lateral stability, then to remove the displaced material from the interior, and drive an iron bound and short timber pile through the interior of the iron pile *down to the bed rock*, and then fill the latter pile with concrete. I am not aware that the system was ever practically verified, although it seems to me some of the so-called Mosely piles were used in or around the city of Boston. Solid wrought iron piles on the Mitchell principle have been driven or screwed to a depth of over 50 feet—I think 53 feet. The usual depth to which they are driven is always controlled by the character of the material and the nature of the load they are intended to carry—its average varies between 9 and 28 feet. As to the present cost of such work, very few are as eminently qualified to form an intelligent opinion as yourself. As regards the best and most economical plan for the work in question, I hardly know what to say. Of course it would be both unkind and unprofessional in me to recommend any plan that would tend to interfere with the views of the present engineer of the work, should one be already employed.

The following occur to me as economical and durable, combined with simplicity of detail and ease of construction, and are based upon an assumed depth of water of 6 to 8 feet, and an overlaying deposit of mud on the bed rock from 5 to 6 feet deep:—

First. Dredge the site to the bed rock. Build on the shore, in sections, and float into place, or build in the water on the site a bulkhead or crib, using 12×12 inch sound *hemlock* or *spruce* timber, previously treated by the "Seely-Pelton" process, and thoroughly fastened with inch square wrought iron drift bolts, 21 inches long, and driven about 3 feet apart. Tie laterally with the same timber, 6×12 inch, and of such length as the dimensions of the work may require. Separate the ties with bolsters of the same timber, 6×12 inch, 3 feet long, never spaced over 12 feet apart, and thoroughly fastened at all intersections with the drift bolts already specified. Fill with broken stone or quarry refuse to any height desired. I

have purposely recommended hemlock or spruce timber because of their economy in point of first cost, and because, when treated by the "carbolic-acidizing" process, they become as desirable and lasting as any of the harder and higher priced woods.

Second. Construct square columns of masonry laid in cement mortar—say 3 feet square under the coping—the latter 18 inches thick and projecting 6 inches on all sides; give the sides of the columns a bâtir or talus of 1 inch per foot; locate the columns 25 or 30 feet apart centers; build them in little caissons open at top, and whose bottoms should form a permanent platform for the masonry to rest upon, made of two courses of 12×12 inch timber previously specified, laid at right angles, and bolted at each intersection; dredge the sites as before, float into place, finish, and remove the caisson sides for use on other columns. Carry the superstructure on compound girders, or **I** beams, of required length and depth.

Third. Similar to the foregoing, except that the stone in the columns may be laid dry (without mortar) by a diver, until low water line is reached, then finished in cement mortar to coping. Of course the foregoing are suggested without any knowledge on my part of the local surroundings, or of the demands or views of the inhabitants of the place.

Trusting what I have said herein may be of some slight service to you, I am, etc.,

Very sincerely yours,

G. Howard Ellers, Chief Engineer.

TROY & WEST TROY BRIDGE CO.:
Chief Engineer's Office,
Troy, N. Y., June 10, 1874.

Franklin Institute.

Hall of the Institute, Sept. 16th, 1874.

The meeting was called to order at 8 P. M., the President, Coleman Sellers, in the Chair.

The Secretary being absent, the President appointed J. B. Knight as Secretary *pro tem.*

The minutes of the last regular meeting, held June 17th, 1874, and the minutes of the special meeting, held June 22d, were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held on the 9th, donations to the Library had been received as follows:—

History of New Sweden, or the settlements on the River Delaware. By Israel Acrelius. From the Historical Society of Penna.

Proceedings of the Academy of Natural Sciences of Philada. Part 1, January, February, March, 1874. From the Society.

Annales des Ponts et Chaussées, for November and December, 1873. Paris. From the Editor.

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins. Vol. 26, 1874; parts 6 and 7. Vienna. From the Society.

Assaying by the Spectroscope. Experiments made in the U. S. Mint, Philada. From Alex. E. Outerbridge, Jr.

Denkschrift zur Erinnerung an die Fünf-und-zwanzigjahrige. Grundungs-Feier des O. I. and A. Vereins, Vienna, 1873. From the Society.

Cincinnati Industrial Exposition. Rules and Lists of Premiums for 1874. From the Board.

Report of the Board of Commissioners Fourth Cincinnati Industrial Exposition, 1873. From the Board.

Jahrbuch der K. K. Geologischen Reichsanstalt. Vol. 24, January February and March, 1874. Vienna. From the Society.

Verhandlungen der K. K. Geologischen Reichsanstalt, No. 1, 1874. From the Society.

Zeitschrift des Architekten und Ingenieur Vereins zu Hanover. Vol. 20, No. 1, 1874. From the Society.

Annales de Chimie et de Physique. Vol. 1, April, 1874. Paris. From the Editor.

Bulletin de la Société d'Encouragement pour L'Industrie Nationale. No. 5, 1874. Paris. From the Society.

Tables des Comptes Rendus des Seances de l'Academie des Sciences. Vol. 77, 1874. Paris. From the Academy.

Journal of the Society of Arts. Vol. 22, from No. 1119 to 1123, inclusive. London, 1874. From the Society.

Monthly Report of the Chief Engineer of the Manchester Steam Users' Association, for January, February, March and April, 1874. From the Association.

Improvements in Steam Engines, with Diagrams. By John Haupt, of Pennsylvania. From the Author.

An Elementary Treatise on Mechanics. Intended for the use of Colleges and Universities. By W. Whewell, D. D. From Mr. C. A. Evans.

Monthly Report of the Chief Engineer of the Manchester Steam Users' Association for the Prevention of Steam Boiler Explosions, for May, 1874. From the Association.

Proceedings of the Royal Geographical Society of London. Vol. 18, No. 3, 1874. From the Society.

Third Report of the Meteorological Office of the Dominion of Canada, for the fiscal year ended June 30th, 1873. By G. T. Kingston, M. A., Superintendent.

Proceedings of the Scientific Meetings of the Zoological Society of London for the year 1873. Part 3, June—December, and Part 1, 1874, containing papers read in January and February. From the Society.

Proceedings and Memoirs of the Literary and Philosophical Society of Manchester, 1868–9. Vol. 3 to 1872–3. Vols. 2 and 4. Third Series. From the Society.

Annales des Ponts et Chaussées, for February and March, 1874. Paris. From the Editor.

Monthly Notices of the Royal Astronomical Society. Vol. 34, No. 8, June, 1874. From the Society.

American Ephemeris and Nautical Almanac for the year 1877. Washington. From the Bureau of Navigation.

Annales des Ponts et Chaussées, for April, 1874. Paris. From the Editor.

Annales de Chimie et Physique, for June, 1874. Paris. From G. Masson, Editor.

Proceedings of the Philosophical Society of Glasgow, 1873–74. Vol. 9, No. 1. From the Society.

Les Cristalloïdes a Directrice Circulaire. Paris. From Le Cte. Léopold Hugo.

Théorie des Cristalloïdes Elementaires. Paris. From Le Cte. Léopold Hugo.

Tables for finding the Latitude of a Place by Altitudes of Polaris. Washington, 1874.

Journal of the Royal Geographical Society. Vol. 43, 1873, London. From the Society.

Monthly Report of the Chief Engineer of the Manchester Steam Users' Association for the Prevention of Steam Boiler Explosions, for June, 1874. From the Association.

Journal of the Chemical Society of London, for May, June, and July, 1874. Vol. 12. From the Society.

Journal of the Statistical Society of London. Vol. 37, Part 2. June, 1874. From the Society.

Geological Survey of Indiana, for 1873. With Maps. From E T. Cox, State Geologist.

Second Annual Message of William S. Stokely, Mayor of the City of Philadelphia, with accompanying Documents, May 14th, 1874. From Hon. Wm. S. Stokely, Mayor.

Report on Weather Telegraphy and Steam Warnings presented to the Meteorological Congress at Vienna, in September, 1873. London. From the Meteorological Committee.

Report of the Meteorological Committee of the Royal Society, for the year ending 31st December, 1873. London. From the Meteorological Committee.

Iron Works of the United States, 1874. Phila. From the Amer. Iron and Steel Assoc.

Annales des Ponts et Chaussées, for May, 1874. Paris. From the Editor.

Metropolitan Museum of Art. New York. 1874.

Eighty-sixth Annual Report of the Regents of the University of the State of New York. Albany, 1873. From the Regents of the University.

Twenty-third Annual Report of the Regents of the University of the State of New York on the Condition of the State Cabinet of Natural History, &c. Albany, 1873. From the Regents.

Twenty-fourth Annual Report on the New York State Museum of Natural History, by the Regents of the University of the State of New York. Albany, 1872. From the Regents.

Fifty-sixth Annual Report of the Trustees of the New York State Library for the year 1873. Albany, 1874. From the Trustees.

Twenty-fifth Annual Report on the New York State Museum of Natural History, by the Regents of the University of the State of New York. Albany, 1873. From the Regents.

Twentieth, Twenty-first and Twenty-second Annual Reports of the Regents of the University of the State of New York on the condition of the State Cabinet of Natural History, &c., 1868–69 and 1871. From the Regents.

Report of the Commissioner of Agriculture for the years 1871 and 1872. Washington. From the Commissioner.

Proceedings of the Royal Geographical Society. Vol. 18, Nos. 4 and 5. London. From the Society.

Proceedings of the American Philosophical Society. Vol. 14, January to June, 1874, No. 92. Philadelphia. From the Society.

Circular of Information of the Bureau of Education. No. 2, 1874. Washington. From the Board of Education.

Annales des Ponts et Chaussées, for June, 1874. Paris. From the Editor.

The Actuary also announced that the Board had approved the arrangement made by the Committee on Instruction with Prof. Haupt, of the University of Pennsylvania, to conduct the drawing school during the coming sessions.

The Chairman of the Committee on Exhibition reported progress, and stated that having been placed in possession of the building at an earlier date than was anticipated, the preparations for the reception of goods were completed a week earlier than the time advertised. The number of applications for space has been very large, and nine-tenths of the available space has been already allotted. Hence many persons who have delayed their applications will undoubtedly be disappointed.

The Secretary pro tem. presented an artist's rotary color stand, the invention of Mr. Samuel James, of this city, a full description of which will be found elsewhere in this number of the JOURNAL.

The President stated that he had been waited on by some of the members of the Commission appointed by the United States government to make experiments towards determining the cause of Steam Boiler Explosions. Some changes have been recently made in this Commismission, and Prof. Joseph Winlock, of Harvard, has been placed at its head. He was selected for his knowledge of the means of exact measurement, and his appreciation of the necessity of a correct record of such experiments. The object of the Commission seems to be to consider all the theories that have been advanced, to test each one carefully, and to eliminate from the test all that cannot be sustained; then to collect all the information of a useful, practical character that is possible. They speak in terms of the highest respect of the experiments conducted by the Franklin Institute, and say they assume them as a basis upon which to build a still more useful superstructure. But the Franklin Institute, at that time, lacked the means which are

now at the disposition of scientists for the careful noting of physical phenomena. They wished their work mentioned to the members of the Franklin Institute, and a request made that if any members of the Institute were cognizant of any reliable means of reading in a bomb proof, some distance removed from the boiler to be exploded, the various conditions of heat, of water, of fire, and of steam, and the various conditions of pressure, as also of motions of parts of the boiler, under strain, they would esteem it a favor if communication would be held with the Commission on the subject. He also stated that there had been very few responses to the circular of the Commission of Sept. 11th, 1873, asking the aid of scientific men, and suggested a committee on this subject, to co-operate with them, and to collect and transmit such information as the members might have to communicate.

Professor Barker said that the Franklin Institute should not be backward in lending its assistance in a work of so much importance, and especially as it was a continuance by the government of what the Institute inaugurated many years ago; the report then made being still regarded as the highest authority on the subject. On motion of Prof. Barker it was

Resolved, That a Committee of three be appointed to co-operate with the Commission.

The Chair appointed on this Committee, Prof. Geo. F. Barker, Robt. Briggs and J. B. Knight; and on motion of Mr. Close, the President, Coleman Sellers, was added.

The President stated that one member of the Commission was in possession of one copy of the original report of the Committee on the causes of Steam Boiler Explosions, and that he had asked if the Institute intended republishing it.

The President also stated that he believed that the republication of the Report might be made profitable, as there would, no doubt, be a demand for it.

On motion of Mr. Orr the attention of the Committee on Publication was called to the propriety of republishing the original Report of the Committee on Steam Boiler Explosions.

On motion, the meeting then adjourned.

J. B. KNIGHT, *Secretary, pro tem.*

Civil and Mechanical Engineering.

THE MESSRS. STEVENS, OF HOBOKEN, AS ENGINEERS, NAVAL ARCHITECTS AND PHILANTHROPISTS.

By Professor R. H. Thurston.

COL. JOHN STEVENS.

The biography of the greatest Engineers, in some respects, that America has yet produced, is still to be written.

Col. John Stevens, of Hoboken, was undoubtedly the greatest engineer and naval architect living at the beginning of the present century.

Without having made any one superlatively great improvement in the mechanism of the steam engine, like that which gave Watt his fame; without having the honor of being the first to propose navigation by steam, or steam transportation on land, he exhibited a far better knowledge of the science and of the art of engineering than any man of his time, and he entertained and urged more advanced opinions and more statesmanlike views, in relation to the economical importance of the improvement of the steam engine, both on land and water, than seem to have been attributable to any other leading engineer of that time.

Col. Stevens was born in the city of New York, in 1749. He was of English descent, his grandfather having come to this country early in the eighteenth century, settled in New York, and married Anne Campbell, granddaughter of Lord Neil Campbell. This gentleman died at Perth Amboy, to which place he had removed after marriage, leaving a son, president of the council of New Jersey.

This son, the father of Col. John, married Miss Elizabeth Alexander, a descendant of one of the first settlers of the state of New Jersey.

Col. John, although as it is stated born in New York, was a resident of New Jersey, and married Miss Rachel Cox, a daughter of John Cox, a prominent citizen of the state, living at Bloomsburg, N. J.

The late Dr. Charles King, then the distinguished President of the Columbia College, thus referred to this great man in a lecture describing the "Progress of the City of New York:"

"Mr. Stevens' attention was first turned, or rather the bent of his genius was developed and directed, towards mechanics and mechanical philosophy, by the accident of seeing in 1787 the early and as now may be said imperfect steamboat of John Fitch, navigating the Delaware river. He was driving in his phaeton on the banks of the river, when the mysterious craft, without sails or oars, passed by. Mr. Stevens' interest was excited—he followed the boat to its landing —familiarized himself with the design and the details of this new and curious combination, and from that hour became a thoroughly excited and unwearied experimenter in the application of steam to locomotion on the water, and subsequently on the land.

"Having been brought by close family connection, into intimacy with Robert R. Livingston (the Chancellor of this state, who married the sister of Col. Stevens,) he induced Mr. L. to join him in these investigations, and they were persevered in at great cost and with little immediate success till Chancellor Livingston, in 1801–2, was sent as minister to France.

"So much, however, was the Chancellor encouraged by the experiments then made, that as early as 1798 he obtained from the Legislature of New York, an exclusive grant for the use of steam on the waters of New York. This, however, became forfeit by the failure to avail within the limited time of its privileges.

"But previously to the Act of '98, the Legislature of New York had, as early as 1787, granted to *James Rumsey* and to *John Fitch*

the exclusive right to navigate the waters of the State with steam-propelled vessels; and on the 9th of January, 1789, John Stevens petitioned the Legislature for a like grant—nothing having resulted from the preceding ones. Mr. Stevens in his petition says that, 'to the best of his knowledge and belief his scheme is altogether new, and does not interfere with the inventions of either of the other gentlemen who have applied to your honorable body for an exclusive right of navigating by means of steam.' The petitioner adds that he 'had made an exact draught of the different parts of his machine, which, with an explanation thereof, he is ready to exhibit.' The prayer of the petition was unsuccessful; but these draughts should be among the papers of the late Col. Stevens, and at this day would be curious.

"Mr. Stevens, meanwhile, never renounced his experiments, nor despaired of success, and in 1804 he actually constructed a *propeller*, (a small open boat, worked by steam), with such decided success, that he was encouraged to go on and build the *Phœnix* steamboat, on his own plan and model, and had her ready almost contemporaneously with, but a little after, the first steamboat of Fulton, the *Clermont*. The success of the Clermont entitled Mr. Fulton and Chancellor Livingston, who was co-operating with Fulton, to the benefit of the law, which had been revived by the State of New York, granted a monopoly of the waters of the State, and thus Mr. Stevens' steamboat was excluded from those waters. On the Delaware, however, and on the Connecticut, he placed boats; and his eminent son, Robert L. Stevens, having embraced his father's views, was now at work with him to improve the known, and invent new resources for accelerated steam conveyance.

"In 1812, just before the commencement of the war with England, and when this State," (New York) "was first addressing itself to the thought of connecting the waters of the lakes with those of the ocean by the Hudson, a thought, very rapidly matured in the sequel, by the delays and *now* incredible cost in transporting troops, artillery and munitions during the war from the sea-board to the lakes, Col. Stevens put forth a pamphlet urging that railroads and steam carriages should be preferred to canals and canal-boats.

"At that day, not a *locomotive* existed in the world, and the only railroads were those few, and short tram-roads, as they were called in England, connecting for the most part coal mines with canals, or other water transportation, and upon which carriages with the ordinary wheels turning upon their axle-trees were drawn by horses. The

carriages were prevented from running off side-ways by a flange raising some inches above the outer edge of the flat rail. In this state of knowledge and experience of railroads it was that, in 1812, Col. Stevens made public, his extraordinary and most sagacious view and accurate calculations respecting, not only the feasibility of applying steam to locomotion on land, but the precise mode of such application; its cost, and its almost illimitable advantages. It seems all but impossible to realize the fact, when carefully reading his description of the railway, of the locomotive, of its wheels made fast to the axle, and revolving not *on* but *with* it, and held by flanges on the inner periphery, from flying off at a tangent, of a whole train, or 'suit,' as he calls it, of railway carriages, 'all firmly attached to each other, and pursuing the same direction;' and of the possible speed they might attain of 40 or 50 miles an hour, but that probably 'it would in practice be found convenient not to exceed 20 or 30 miles an hour;' it seems I repeat, almost impossible to realize the fact that, at that day no locomotive existed except in the creative and ingenious mind of the writer; and that no railroad, such as he needed for his unrevealed plan had ever been laid down.

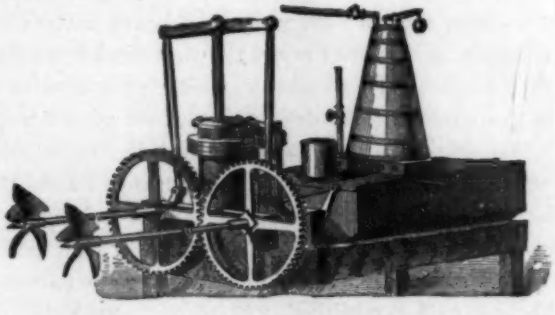
"If he had seen then, what he lived to see afterwards, and from the handiwork and genius mainly of his son Robert, on the Camden and Amboy Railroad, the spectacle, ever impressive, however frequently witnessed, of long trains of cars sweeping on with the rapidity of the pigeon's flight, he could not have described with more absolute accuracy all the details of such a train, such a road, and such a locomotive, than is done in the prophetic pamphlet of 1812.

"He was treated as a 'visionary projector.' Time has vindicated his claim to the character of a far-seeing, accurate and skillful practical experimentalist and inventor; and who can estimate, if at that day, acting upon the well considered suggestion of President Madison, 'of the signal advantages to be derived to the United States from a general system of internal communication and conveyance,' Congress had entertained Col. Stevens' proposals, and after verifying by actual experiment upon a small scale, the accuracy of his plan, had organized such a 'general system of internal communication and conveyance;' who can begin to estimate the inappreciable benefits that would have resulted therefrom to the comfort, the wealth, the power and above all to the absolutely impregnable union of our great Republic and all its component parts?

"All this, too, Col. Stevens embraced in his views; for he was a statesman, as well as an experimental philosopher; and whosoever shall attentively read this pamphlet will perceive that the political, financial, commercial, and military aspects of this great question were all present to Col. Stevens' mind; and he felt that he was fulfilling a patriotic duty when he placed at the disposal of his native country, these fruits of his genius.

"The offering was not accepted. The THINKER was ahead of his age; but it is grateful to know that he lived to see his projects carried out, though not by the government; and that, before he finally, in 1838, closed his eyes in death, at the age of 89, he could justly feel assured that the name of *Stevens*, in his own person and that of his sons, was imperishably enrolled among those which a grateful country will cherish."

The whole life of Col. Stevens, as remarked by the same writer, "was devoted to experiments, at his own cost, for the common good."



MACHINERY OF TWIN SCREW STEAMER OF 1804.

A model of the little steamer built in 1804, is preserved in the lecture room of the department of mechanical engineering at the STEVENS' INSTITUTE OF TECHNOLOGY and the machinery itself, consisting of a high pressure "sectional" or "safety" tubular boiler as it would be called to-day, a high-pressure condensing engine with rotating valves, and with twin screw propellers is given a place of honor in the model room or museum, where it contrasts singularly with the mechanism contributed to the collection by manufacturers and inventors of our own time. The hub and blade of a single screw, also used with the same machinery, is also to be seen there.

The British Patent on the boiler, issued to John Cox Stevens, a son of the inventor, is also to be seen in the Relic corner of the lecture room of the writer.

A water tubular boiler, also, made for a small locomotive built somewhat later is another relic testifying to the ability of this great man. In his published pamphlet on railroads, Col. Stevens writes May 15th, 1812, "I can see nothing to hinder a steam carriage from moving on these ways, with a velocity of one hundred miles per hour," and, in a foot note, "This astonishing velocity is considered here as merely possible. It is probable that it may not in practice be convenient to exceed twenty or thirty miles an hour.

"Actual experiments, however, can alone determine this matter, and I should not be surprised at seeing steam carriages propelled at the rate of forty or fifty miles an hour."

Col. Stevens designed a peculiar form of iron clad in the year 1812, which has been since reproduced by no less distinguished and successful an engineer than the late John Elder, of Glasgow, Scotland. It consisted of a saucer shaped hull, carrying a heavy battery and plated with iron of ample thickness to resist the shot fired from the heaviest ordnance then known. This vessel was secured to a swivel, and was anchored in the channel to be defended. A set of screw propellers driven by steam engines and situated beneath the vessel, where they were safe against injury by shot, were so arranged as to permit the vessel to be rapidly revolved about its centre. As each gun was brought into line of fire it was discharged, and was then reloaded before coming around again. This was probably the earliest embodiment of the now well established "Monitor" principle. This was probably the first iron clad ever designed.

This great engineer and inventor was therefore far in advance of his time. The sectional steam boiler only just becoming a standard type; high pressure steam with condensation has just become generally adopted; the screw only came into use forty years later when Ericsson, Smith and Woodcroft came forward with it, and twin screws are hardly yet familiar to engineers. The revolving battery protected by iron plating is another of what are generally considered recent devices; and the peculiar Stevens revolving ship is reproduced by Elder sixty years later.

The sons of Col. John Stevens assisted their father in his work and inherited their father's mechanical skill.

The designer of the celebrated Stevens Battery was one of these sons, and the name of Robert L. Stevens is not less famous than that of John Stevens.

ROBERT L. STEVENS.

He took an active part with his father, very early in life, and in 1808, went around by sea from New York to Philadelphia with Captain Bunker, in the "Phœnix," the first sea voyage which was ever made under steam.

It was Robert L. Stevens who became so well known as a successful steamboat builder, and as one of the originators of the best lines of steamers on the Delaware and Connecticut, and, after the expiration of Fulton's monopoly, on the Hudson. Much of his best work was done during his father's life-time.

He made many extended and most valuable as well as interesting experiments on ship propulsion, expending much time and large sums of money upon them, and many years before they became generally admitted, he had arrived at a knowledge not only of the laws governing the variation of resistance of excessive speeds, but he had determined and had introduced into his practice those forms of least resistance and those graceful water lines which have only recently distinguished the practice of other successful naval architects.

Referring to his invaluable services, President King, who seems to have been the first to thoroughly appreciate the immense amount of original invention, and the surprising excellence of the engineering work of this family, says, in 1851: "The extent, variety and value

of Mr. R. L. Stevens' labors and inventions in mechanics, should have more fitting commemoration than can be given in any passing notice by one unskilled, as is the writer of this, in the mechanical arts. Yet he cannot suffer this allusion to Mr. Stevens to go forth without attempting at least to enumerate some of the many services and ingenious inventions and appliances of that gentleman in steam, in gunnery, and in mechanics. From the time when a mere boy, in 1804–5, he was zealously working in the machine shop at Hoboken, up to the passing hour, he has given his time, his faculties, and his money, to what may be justly described as *experimental philosophy*, and the results have been of great public benefit. Of some of them, the following chronological record may bear witness:

"1808. Hollow or concave water lines in the bow were introduced for the first time in the steamboat Phœnix—the first steamboat that ever breasted the ocean; these lines, under the name of 'wave lines,' are now, as I understand, claimed abroad as a recent English application. On the same vessel, in 1809, he first used *vertical buckets* on pivots.

"1809. Suspended the projected guard beam by iron rods from above—now universal in river steamers.

"1813–14. The war with England being then in progress, he invented, after numerous and most hazardous experiments, the *elongated shell*, to be fired from ordinary cannon. Having perfected this invention, he sold the secret to the United States, after making experiments to prove their destructiveness, so decisive as to leave no doubt of the efficacy of such projectiles. One of these experiments was made at Governor's Island, in the presence of officers of the army, when a target of white oak, four feet thick and bolted through and through with numerous iron fastenings, was completely destroyed by a shell weighing 200 lbs. and containing 13 lbs. of best battle powder; this solid mass of wood and iron was torn asunder; the opening made was large enough, as the certificate of the officer commanding, Col. House, stated, for a man and horse to enter.

"These shells are free from the danger accompanying ordinary shells, for they are *hermetically sealed*, and suffer no deterioration from time. Some of these, after being kept 25 years, by way of proving their safety till needed and as needed, were tested by exploding gunpowder under them, and then were taken to high places and let fall on rocks below, and all without causing them to explode.

After this they were plunged into water, and then being put into the cannon, were fired, and upon striking the object, exploded with devastating effect.

"1813. First to fasten planks and braces of steamboats (in the Philadelphia) with screw bolts, and to place diagonal knees of wood and iron inside of them.

"1815. First to use steam expansively in steamboat Philadelphia.

"1818. First to burn anthracite coal in a *cupola* furnace, and subsequently to introduce this fuel in fast steamers—the Passaic being the earliest to use it.

"1822. To substitute for the heavy, solid cast-iron walking-beam of steamboats, the skeleton wrought-iron walking-beam (in the Hoboken), now in universal use.

"1824. First to place the boilers on the guards, and to divide in steamboat Trenton the buckets on the water-wheel.

"1827. First on steamboat North America to apply successfully artificial blast to the boiler furnace by means of blowers, and in the same boat to apply what is technically known as the *hog frame*, now general in fast boats, consisting of the large timbers on the sides to prevent the boat from bending in the centre, or as it is called, being *hogged*.

"1828. First to apply the steel spring *bearings* under centre of the wheel shaft of the steamer New Philadelphia.

"1832. First to introduce in the New Philadelphia perfect *balance valves*, now in general use in steamboats, which enabled one man to work the largest engine with ease. In the same year he used braces to the connecting rod, thus strengthening it and preventing its tremulous motion.

"1832–3. Constructed a boat (between Camden and Philadelphia) capable of navigating through solid, heavy ice. In the same year he constructed and introduced tubular boilers, having the fire under the bottom and returning through the tubes.

"1840. Improved the packing of pistons for steam engines by using the pressure of steam instead of hemp, steel springs, india rubber, etc., to retain the metallic packing ring against the surface of the cylinder. One of these rings which has been in use on board steamer Trenton since 1840, is at this day in good order.

"1841. The *Stevens Cut-off*, by means of main valves worked by two eccentrics, invented by R. L. Stevens and his nephew (for me-

of Mr. R. L. Stevens' labors and inventions in mechanics, should have more fitting commemoration than can be given in any passing notice by one unskilled, as is the writer of this, in the mechanical arts. Yet he cannot suffer this allusion to Mr. Stevens to go forth without attempting at least to enumerate some of the many services and ingenious inventions and appliances of that gentleman in steam, in gunnery, and in mechanics. From the time when a mere boy, in 1804–5, he was zealously working in the machine shop at Hoboken, up to the passing hour, he has given his time, his faculties, and his money, to what may be justly described as *experimental philosophy*, and the results have been of great public benefit. Of some of them, the following chronological record may bear witness:

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chanical ingenuity and skill run in the blood) F. B. Stevens; these are generally used now in the river boats and in the ocean steamers built in New York. In the same year he invented and applied on the Camden and Amboy railroad the double-slide cut-off, for locomotives and large engines; and improved locomotives for transporting goods, etc., by using eight wheels, and with increased adhesion was enabled to turn short curves with little friction on the flanges; also used *anthracite* as a fuel to great advantage on the heavy engines, weighing 24 tons, with wheels of 42 inches diameter, cylinders of 18 inches, and 34 inch stroke.

"1842. Having contracted to build for the United States government a large war steamer, shot and shell proof, R. L. Stevens built a steamboat at Bordentown for the sole purpose of experimenting on the forms and curves of propeller blades, as compared with side-wheels, and continued his experiments for many months, the result of which we may yet hope to see in an iron war steamer that will be *invincible*, and should be so named. While occupied with this design he invented about 1844, and took a patent for, a mode of turning a steamship of war on a pivot, as it were, by means of a cross propeller near the stern, so that if one battery were disabled, she might in an instant almost, present the other.

"1848. This year he succeeded in advantageously using *anthracite* in fast passenger locomotives.

"1849 witnessed the successful application of air under the bottom of steamer *John Neilson*, whereby friction is so much diminished, that she has actually gone at the rate of 20 miles an hour; this was the invention of R. L. Stevens and F. B. Stevens. The *John Neilson* also has another ingenious and effectual contrivance of R. L. Stevens, first used in 1849, for preventing ill consequences from the foaming of the boiler. In conclusion of this dry and imperfect chronological recital of some of R. L. Stevens' contributions to the mechanic arts, to public convenience and national power, as well as renown, it must be added that Mr. Stevens is himself the modeller of all the vessels built by or for him, and that many of our fastest yachts are of his moulding; and especially the *Maria*, which beat without difficulty the victorious America, which in her turn carried the broom at her mast-head through the British Channel, distancing all competitors, as she continues to do, I believe, under her new owner in the Mediterranean.

"Of such a man, not only the mechanics of our city" (New York)

"among whom he has worked, and is well known, but the nation may well be proud."

The Camden and Amboy railroad was projected and largely sustained by the aid, both pecuniary and other, of the Messrs. Stevens. The locomotives were built from the designs of Robert L. Stevens, some at the works in Hoboken, and some in English workshops. It was here that he introduced the T-rail, and when his design was pronounced an impossible one to roll, he himself went abroad and showed that it could be done and how.

In 1833, in a letter now framed and carefully preserved in the "Relic Corner" of the Department of Engineering in the Stevens Institute of Technology, Robert Stephenson writes to Robert L. Stevens, deprecating the general inclination of American Engineers to build light locomotive engines, and stating that he had completed the design of an engine,—of which he gave a neat sketch, made to scale,—which weighs nine tons, and is capable of hauling "one hundred tons dead load sixteen or eighteen miles an hour on a level." He urges Mr. Stevens, whom he seems to consider an engineer of correct views, to assist him in effecting sales.

Mr. Stevens' experiments on the effect of the impact of shot and shell upon iron plating were commenced very early, and were carried on at great expense of time and money. As early as 1837 he had perfected a plan of an iron clad war vessel, and in August, 1841, his brothers James C. and Edwin A. Stevens, representing Robert L., addressed a letter to the Secretary of the Navy, proposing to build an iron clad vessel of high speed, with all its machinery below the water line, and submerged screw propellers.

The armament was to consist of the most powerful rifled guns, loading at the breech, and provided with elongated shot and shell.

After some delay, during which Mr. Stevens and his brothers were engaged with their experiments and in perfecting their plans, a contract was made in 1843, and the keel of an iron clad was laid down in a dry dock which had been constructed for the purpose at great cost.

This vessel was to have been 250 feet long, of 40 feet beam, and 28 feet deep. The machinery was designed to furnish 700 indicated horse power. The plating was proposed to be 4½ inches thick,—the same weight of armor as was adopted ten years later by the French for their comparatively rude constructions.

In 1854, such marked progress had been made in the construction

of ordnance that Mr. Stevens was no longer willing to proceed with the original plans, fearing that were the ship completed, it might prove not invulnerable and might throw some discredit upon its designer as well as upon the navy of which it was to form a part.

The work, which had, in those years of peace, progressed very slowly and intermittently, was therefore stopped entirely, the vessel given up and in 1854 the keel of a ship of vastly greater size and power was laid down.

The new design was 415 feet long, of 45 feet beam and of something over 5000 tons displacement. The thickness of armor proposed was 6¾ inches,—2½ inches thicker than that of the first French and British iron clads,—and the machinery was designed by Mr. Stevens to be 8624 indicated horse power, driving twin-screws and propelling the vessel twenty miles or more, an hour.

As with the preceding design, the progress of construction was intermittent and very slow. Government advanced funds and then refused to continue the work, successive administrations alternately encouraged and discouraged the engineer and he finally, cutting loose entirely from all official connections, went on with the work at his own expense.

The remarkable genius of the elder Stevens was well reflected in the character of his son, and is in no way better exemplified than by the accuracy with which, in this great ship, those forms and proportions both of hull and machinery were adopted which are to-day, a score of years later, recognized as most correct under similar conditions.

The lines of the vessel, as shown on plate I. in the descriptive article already published in this JOURNAL, for September, are beautifully fair and fine and are what J. Scott Russell has called "wave lines," or trochoidal lines, such as Rankine has shown to be the best possible for easy propulsion. The proportion of length to midship dimensions is such as to secure the speed proposed with a minimum resistance and to accord closely with the proportions arrived at and adopted by common consent in past trans-oceanic navigation by the best,—not to say radical,—builders.

Even in the minor details of his machinery Mr. Stevens had, by careful experiment, determined for himself, and had adopted in his practice, proportions which were only hit upon by the majority of engineers many years later. In much of this experimental work, including his researches in naval science, he was assisted by his

Nephew Francis B. Stevens, still the superintendent of the establishment of the Camden and Amboy R. R. at Hoboken.*

Mr. Stevens conducted his experiments and did his own work with great secrecy as it was considered a matter of national importance that no knowledge of his work should reach foreign powers, and Mr. Norman Scott Russell who was probably the first to obtain any accurate information relating to the ship, stated before the British "Institute of Naval Architects," that, in 1858 or 1860 few persons knew "that Mr. Stevens had made experiments upon armor plates for ships of war as early as the year 1816, and nobody in this country" (Great Britain) "entertained the slightest suspicion that the American Government had concluded a contract with the Messrs. Stevens, the fathers of this new system, to construct an iron plated battery as early as 1843, though the commencement of this vessel was delayed by official interference until some years later. So well indeed had they kept their secret that the late Sir Howard Douglass, who took so deep an interest in the improvement of the Navy, and prided himself on being kept well informed of all that was being done in the naval or military matters of foreign countries, wrote as late as 1860, that no iron-cased vessel was built, or being built in the United States."

The guns proposed in 1843 were large for that time, "64 pounders" and the principle, now recognized as a cardinal principle, "a smaller number of the largest guns, rather than a larger number of small guns," was upheld from the beginning by Mr. Stevens. The larger vessel was designed for the heaviest guns that could be constructed at the time. These immense guns were to be mounted on turntables and worked very much as the guns of the "monitors" are handled.

The death of Robert L. Stevens occurred when this larger vessel had advanced so far towards completion that the hull and machinery were practically finished, and it only remained to add the armor-plating, and to decide upon the form of fighting house, and upon the number and size of guns.

The construction of the vessel, which had proceeded slowly and intermittently during the years of peace, as successive administrations had considered it necessary to continue the payment of ap-

* The same engineer to whose intelligence, energy and public spirit, conjoined with the liberality of the United Railroads of New Jersey, we are indebted for that knowledge of the causes and methods of steam boiler explosions which was acquired in 1871, and of which extended accounts appeared in this JOURNAL.

propriations, or had stopped it temporarily in the absence of any apparent immediate necessity for its continuance, was again interrupted by his death in the year 1856.

EDWIN A. STEVENS.

His brothers, J. C. and E. A. Stevens, had taken an active and intelligent interest in the great scheme, attempted to secure from the government authority to complete the ship.

The last named addressed several letters to the Navy Department on the subject, but received no substantial encouragement, although offering to complete the vessel at his own expense, and agreeing:

"1st. That she shall be impenetrable to the most destructive missile fired from the most powerful gun (with its ordinary service charge) now used in our own or in any European naval service, to be tried upon her at short range—say 220 yards.

"2d. That she shall have greater speed than any other iron-clad war steamer in the world.

"3d. That she shall be more manageable and more quickly turned and manœuvered than any other large armed sea-going steamer.

"4th. That she shall have an armament capable of throwing a broadside at least equal to that of any ship now afloat."

The vessel was to be tried on completion, and accepted and paid for by the government only when these conditions were fulfilled. But even these terms the government seemed indisposed to accept. A board appointed to examine the vessel, reported a description of the vessel with criticisms of some of its details. Mr. Stevens presented

to the government the favorable professional opinions of nearly every distinguished engineer and shipbuilder in the country, including R. L. Loper, Samuel Harlan, Jacob S. Neafie, Theodore Birely, Washington Jones, Messrs. Coryell and Erastus W. Smith, and also Professor Henry.

Mr. Stevens, to settle a doubt expressed as to the value of the plans proposed for loading and working the guns by steam—one of Robert L. Stevens' most important inventions—built a small vessel, the "Naugatuck," to practically demonstrate its efficiency in actual warfare.

This steamer was 100 feet long, 20 feet beam, and 7 feet depth of hold, with compartments at each end to receive water for the purpose of sinking her to her "fighting draught" when in action.

The name of this little vessel has become historical.

Under the command of W. W. Shippen, Esq., she took part in the engagement on the James river, during the attacks of the forces of the United States upon the defences of Richmond, and rendered valuable assistance until disabled by the explosion of the heavy Parrott rifle with which she was armed. Mr. Stevens has never received credit to which this characteristically liberal and patriotic enterprise should entitle him.

Mr. Edwin A. Stevens finally died, leaving this task still unaccomplished, and the vessel remained unfinished on the hands of his executors.

In the will of Mr. Stevens he made two bequests which testify to the public spirit and "large mindedness" of the man.

The most important was that by which he provided for the foundation of the STEVENS INSTITUTE OF TECHNOLOGY. Nearly a million of dollars was appropriated directly or indirectly to this great object, and this noble institution is a finer monument to his memory than is St. Paul's Cathedral to that of its great architect, Sir Christopher Wren.

Another provision of the will directed his executors to complete the iron clad with funds appropriated to that purpose, amounting to one million of dollars, and when completed to present the finished vessel to New Jersey, his native State.

The executors proceeded to carry out their instructions at once, appointing General McClellan engineer in charge, and, on his recommendation, Mr. Isaac Newton was engaged as assistant engineer.

Under the advice of the engineers, it was determined to make radi-

cal changes throughout, to place the vessel in proper condition to meet successfully those more formidable antagonists that recent rapid advances in naval science had rendered far more formidable than any existing at the time of the death of the designer.

The declared object had been, from the first, to set afloat a vessel that should be the most formidable vessel on the ocean.

It was therefore concluded to introduce an inner skin, transverse water tight bulk heads and coal bunkers, to build new engines, and to transform the vessel into an iron clad which, while retaining the high speed originally proposed by Mr. Stevens, should carry the heaviest ordnance yet built behind armor of unexampled thickness, and with undiminished power as a steam ram, capable of exerting that power with considerably increased economy of fuel.

The hull and machinery were altered in accordance with this plan, and the modified hull and new machinery are now in the shape described in the specifications and illustrated in the drawings already published in the JOURNAL OF THE FRANKLIN INSTITUTE.*

The sum appropriated for the completion of the vessel proving insufficient to supply armor and armament, the work of reconstruction was suspended, leaving the details of internal arrangement and the plan of armor and armament to be determined by the state of naval science when the funds required for the purpose should be secured.

It is probably very fortunate that this latitude was allowed the purchaser.

A question arising as to the real ownership of the vessel, the matter was referred to the Court of Chancery, and by act of the State Legislature a sale was ordered, the proceeds to be paid into Court to await the decision, and Governor Parker, Vice Chancellor Dodd, the Hon. W. W. Shippen and the Rev. S. B. Dod, were appointed a Commission with power to effect the sale.

What is to be the destiny of this noble vessel cannot now be even conjectured, but will soon be determined, the sale taking place on the second day of November next. As the vessel is offered either as an entirety or in parts, it is not impossible that the most celebrated of all iron plated vessels, never yet engaged in actual warfare, the fastest war steamer in the world, with its possibility of becoming the most powerful steam ram, the fleetest of torpedo ships or the most formid-

*See this Journal, lxviii, p. 165, Sept. 1874.

able of iron clads, should fall into hands of those who will convert her to mercantile use, either as a sailing vessel or a steamer, or even break up hull and machinery to obtain the exceptionally excellent material of which they are constructed.

Even this would be better, however, than the purchase of the vessel by a foreign government, liable at any time to turn this remarkable product of the ingenuity and skill of one of the greatest of American mechanics against his native country. This is not unlikely to occur should our government neglect this last opportunity to secure the vessel.

The impossibility of securing the necessary appropriations to keep our naval force up to the standard which ordinary prudence should have established, or even to preserve those iron-clads already built, has had the effect of reducing us to dependence upon our fortunately efficient Torpedo Corps of the Army and Navy, and has made us comparatively powerless for offence. This fact makes it the more necessary that no opportunity should be lost to secure an effective vessel for our own naval force or to prevent such an addition to a foreign navy.

Whatever may be the result, however, the name of Robert L. Stevens will be long remembered as one of the greatest of American mechanics, the most intelligent of naval architects and as the first and one of the greatest of those to whom we are indebted for the commencement of the mightiest of revolutions in the methods and implements of modern naval warfare.

The length of this sketch will probably be admitted to be fully justified by the interest and importance of its subject. American mechanical genius and engineering skill have rarely been either promptly recognized until very recently and no excuse is required for any attempt to place such splendid work as that of the Messrs. Stevens, in a light which shall reveal both its variety and extent and its immense importance.

Said Henry Bell, nearly three quarters of a century ago, when he and Fulton and Stevens were at work on the great problem, "I will venture to affirm that History does not afford an instance of such rapid improvement in commerce and civilization as that which will be effected by steam vessels," and when it has been shown what has been accomplished in this great work by each of these several pioneers,

there is no further need to attempt compliance with Milton's injunctions:—

"* * * * Build him
"A monument and plant it round with shade
"Of laurel, evergreen and branching palm,
"With all his trophies hung and acts inroll'd
"In copious legend, or sweet lyric song."

STEVENS INSTITUTE OF TECHNOLOGY,
Hoboken, N. J., September, 1874.

BELTING FACTS AND FIGURES.

BY J. H. COOPER.

[Continued from Vol. lxvii, page 403.]

On the Creep of Belts.—"It is generally considered by those who have had experience in the matter, that there is a slight slip in all belts, however large they may be in proportion to the power transmitted, and however tightly they may be stretched. Perhaps in the case in which a belt is much larger than is required, it would be better to say that there is a slight *creeping*, instead of a slip, this creeping being caused by the change in tension of the belt as it moves from the tight to the slack side in passing over the pulley.

"Where belts are driven at a high velocity, it is found that the centrifugal force still further changes the ratio of speeds of the driving and driven pulleys, in some cases decreasing the tension of the belt, and in others acting in the contrary way. This may be explained in the following manner: If the pulleys over which the belt is stretched are quite close together, the two parts of the belt will be nearly straight, so that there will be little change of tension, whether the belt is at rest or in motion, and the centrifugal force diminishes the tension. If the pulleys are a considerable distance apart, the two portions of the belt will be curved, and part of the centrifugal force acts in increasing the length of the belt, and thus increases the tension, instead of diminishing it, as in the former case. In ordinary cases, where the velocity of a belt is not very great, it is probably not necessary to consider the action of centrifugal force.

"The writer is frequently engaged in making tests of machinery, and finds it convenient to obtain a record of the speed of shafts and

engines. At a recent test of power in a large factory some interesting data were obtained in relation to the creeping of belts, and it is believed that these results may be of interest and value to other engineers."

The case was one in which the size of the belts was largely in excess of that actually required for the transmission of the power, and the velocity with which they moved was quite moderate. Under these circumstances it was to be expected that the difference between the actual ratio of speeds, and that which should have been obtained if there had been no slip or creep, would be less at an increased than at a diminished rate of speed, if the changes in speed were so slight as not sensibly to vary the centrifugal force. For the purposes of the test, counters were attached to the driving engine and to the shaft in a distant part of the building, the power being transmitted to that shaft by five belts. Simultaneous readings of the two counters were taken every minute for the space of an hour. The result of several of these observations for intervals of five minutes each, is given below:

Revolutions of engine.	Revolutions of shaft.	Ratio of speed.
159	417	2.623
153	397	2.595
154	403	2.617
148	383	2.588
Total... 1848	4816	2.612

"It will be observed that as the speed was decreased, there was a perceptibly greater creep in the belts. It having been found advisable to increase the speed of the engine and shafting, similar tests were made, when this change was effected, and a few of the results are given below:

Revolutions of engine.	Revolutions of shaft.	Ratio of speed.
205	538	2.624
204	535	2.623
203	532	2.621
206	541	2.626
208	544	2.615
Total... 2457	6432	2.618

It is generally known that there is a best speed for a belt under given conditions, and that if this speed is either increased or diminished, the tension of the belt will be diminished. It appears from these latter results that this speed was about reached by the change, so that the belts were transmitting under the most favorable conditions as regards speed.

A careful measurement of all the pulleys transmitting the power from the engine to the shaft in question, increasing their diameters by the mean thickness of the belts passing over them, shows that the actual ratio of speeds of engine and shaft should have been as 1 to 2·625, so that there was an average slip or creep, in the first case of 0·495 per cent, and in the second, of 0·267 per cent.

R. H. BUEL, M. E.

80 Broadway, N. Y.

The Engineering and Mining Journal, Feb. 28th, 1874.

Mr. Jno. Mason, of Bulkley, Barbadoes, presents a novelty in the way of belting that he has been using for driving centrifugal machines for the past two years. He says:—"I found leather belting gave so much trouble and was so expensive that I was induced to try a belt made of raw cow's hide, simply dried in the sun, cut perfectly straight, and the joints carefully stitched (square and even) with common saddler's hemp. I find in practice that a belt of this description will last longer than from leather belts, besides being only one-fourth the cost. I am driving a line of 3 inch shafting with an 8 inch belt of this description with every satisfaction. They are now used here for driving Weston's centrifugals, as well as those of Manlove and Elliott's. I make them 2½ inches broad for driving the latter."

"*Engineering*," *June 19th*, 1874.

Mr. S. S. Spencer, Supt. of Conestoga Mills Nos. 2 and 3, at Lancaster, Pa., has kindly furnished me with the following particulars of the main driving belts now in use in these two mills.

Mill No. 2 is driven by an horizontal condensing Corliss engine having a 30 inch cylinder, 6 feet stroke, running 52½ revolutions per minute. The fly wheel is 22 feet in diameter, and weighs 25 tons. It has teeth on its periphery of 5·183 inches pitch, 18 inch face, and drives a "jack" 9 feet 7½ inches diameter on a counter shaft 9 feet 10 inches below the engine shaft. On this counter shaft are three

9 feet 6 inch pulleys, each driving a 5 feet pulley on the main lines as here shown. (Fig, 1.)

The belts running to right and left are each 23½ inches wide, and each transmits 125 horse power. The middle belt is 29 inches wide and transmits 175 horse power. All are of double leather.

Mill No. 3 is driven by a horizontal non-condensing Corliss engine of 28 inch cylinder, and 5 feet stroke, running 50½ revolutions per minute, having a 22 feet diameter fly wheel pulley of 17 tons weight.

Two 14½ inch double leather belts on the fly wheel run to right and left, driving 7 feet pulleys on the line shafts, thus: (Fig. 2.)

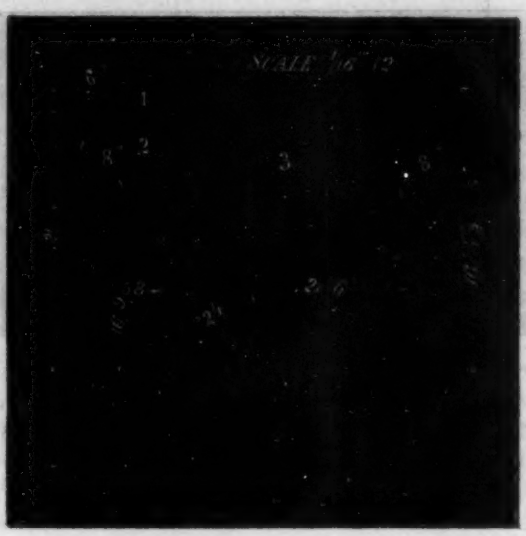
The belts transmit 250 horse power, have been in use since 1852, and are doing well. If we suppose each belt does half the work, we will have 33·64 square feet of belt in motion per minute per horse power.

Another case worthy of note is that of a 16 inch cylinder, 48 inch stroke horizontal Corliss engine, with 14 feet diameter fly wheel pulley, making 65 revolutions per minute, carrying a 12 inch double leather belt over a 5 feet pulley on the line shaft, which is located under the second floor of the factory in the usual way, and 17 feet horizontally distant from the engine shaft. This engine is doing 90 horse power, and has been running for 8 years. The velocity of belt surface here is 2860 feet per minute, and gives 31·77 square feet of belt per minute per horse power.

Mr. Spencer further says: "Whether a belt is more or less liable to slip on the larger pulley, I say less in all cases. There is great advantage in covering the smaller pulley with leather where much work is required. It is much better to use narrow belts and pulleys of large diameter than wide belts and pulleys of small diameter. This fact is probably less understood and appreciated than any other in connection with belts and pulleys. Belts require care in their application and management. I have belts that have been in use 22 years under rather unfavorable circumstances, and look to-day as if they would last 10 years longer.

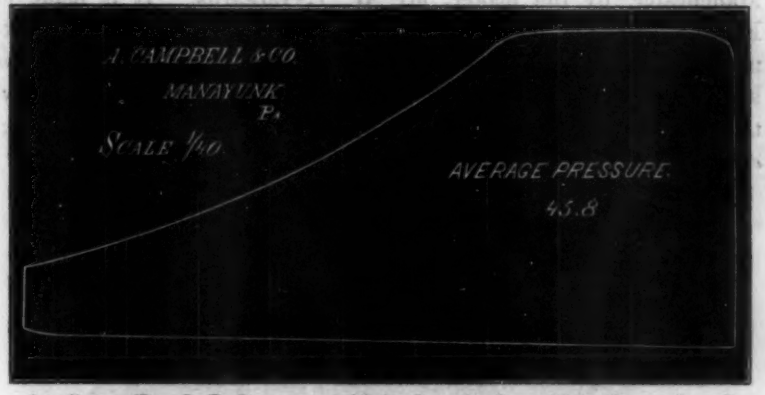
Mr. W. B. Le Van presents this and the next case of driving belts:

At A. Campbell & Co.'s factory, Manayunk, the motive power is transmitted by three belts to three separate line shafts, as shown below, (Fig. 3.)



Belt No. 1 to the upper 6 feet pulley is 17 inches wide. Belt No. 2 to the 8 feet pulley beneath, is 21½ inches wide. Belt No. 3 to the 8 feet pulley, to the right in the cut, is 26½ inches wide. The belts are all double leather, and run from the pulley fly-wheel on the engine-shaft, which is 24 feet diameter, 6 feet width of face, and weighs, with its shaft 43 tons. The engine is a horizontal Corliss, with 30 inch cylinder, 5 feet stroke, making 52 revolutions per minute, driving about 20,000 spindles and the usual connected machinery.

Below (Fig. 4) we give an Indicator card taken from engine on March 2d, 1874, under a boiler pressure of 85 lbs. Scale of card 30 lbs. to the inch, average pressure 45·8 lbs., horse-power exerted by one pound of pressure 11·14, estimated power to run engine only 16·71; hence we have $(11{\cdot}14 \times 45{\cdot}8) - 16{\cdot}71 = 493{\cdot}5$ horse-power. Some of the cards ran as high as 47 lbs. average pressure. The average of 8 cards was 456·74 horse-power.



At Great Bend, Indiana, an 18 inch cylinder, 48 inch stroke, Corliss engine, under 90 lbs. of steam, at 65 revolutions per minute, transmits 190 horse-power usually, and at times 222 horse-power, through the medium of a 22 inch single leather belt over a 12 foot fly-wheel pulley to a 42 inch pulley on the line shaft.

This belt was originally 24 inches wide, but using the figures above we get 23·64 and 20·23 square feet of belt in motion per minute per horse-power, respectively. This is the hardest worked belt of any yet noted.

A single leather belt in good driving condition has been frequently used in testing car wheel forcing presses. Under the following conditions this belt was repeatedly found to do the work. Belt 6 inches wide, pulley 24 inches diameter, of iron smooth turned, crank 2

inches radius, plunger 15-16ths inch diameter in an 1¼ inch barrel, hydraulic pressure 7000 pounds per square inch; hence we have:

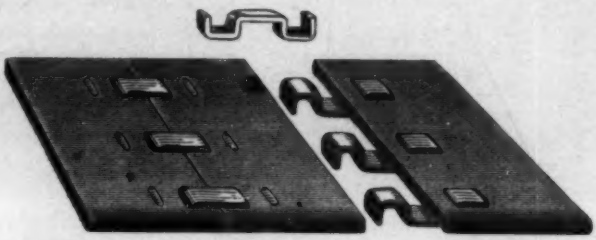
$$\frac{(\text{area of } 1\tfrac{1}{4} \text{ inches} - \text{area of } 15\text{-}16\text{ths})\ 7000}{6 \times 6} = 104{\cdot}33.$$

From this we may safely conclude the maximum driving force of a single leather belt to be near 100 lbs. per inch of width.

From Leigh's *Science of Modern Cotton Spinning*, 1873, we copy the following rule for double leather belts: "Multiply the square inches of belt contact on the smaller pulley by half the speed of the belt in feet per minute and divide by 33,000. The quotient gives the horse-power to which the belt is equal."

This rule provides for twice the quantity of belt needed, as shown by the examples from actual practice quoted above.

Largest English Belt. — "A leather belt, said to be the largest ever made in this country, is now being exhibited at 20 Market-place, Manchester, by the maker, Mr. W. T. Edwards. It is made of English leather 36 inches in width, and is 83 feet long, in two thicknesses, and without a cross joint in the whole length. The belt has been made for Messrs. Witham Brothers, cotton spinners, of Burnley, to transmit 300 horse-power off a drum 16 feet diameter."—*Engineering, March* 27, 1874.



Champion Belt Hook.—The above cut (Fig. 5) will convey a correct idea of the manner of adjusting this hook. It will be observed that the substantial double bearing of each hook precludes the possibility of its "tearing out." Shortening or taking up slack in belts is only the work of a moment, when this hook is used. It is conceded that no belt fastening is equal to this for strength. It is less expensive than the *Blake stud*, or than *lace leather*, and although it costs more than the "C" hook, it is in the end cheaper, because it retains its original shape in the belt, and the same hook can be used over and over again. It can be adjusted with greater ease and in much less time than any other belt fastening.

Tests of Shafting- by SAMUEL WEBBER, C. E., Manchester, N. H., 1874.

DATE.	PLACE.	Length.	Diameter.	Weight.	Weight of Palleys.	Total Weight.	No. of Bear'gs.	Rev. per Minute.	Ft. Lbs.	Horse-Power.	Coeff. Friction.	REMARKS.
												CONTINUOUS OILING. [Kerosene Oils mixed.
April, 1871	Amoskeag Mills,	8 ft. 6 in.	2¼ inc.	101 lb.	577 lb.	678 lb.	2	216	49	·089	·0336	Single Counter. Dreyfuss Pat. Oiler. Sperm and
"	"	34	"	404	1,974	2,378	8	216	196	·357	·0413	4 Count's like above. Connected with Belts. Same
"	"	114	"	1,366	1,859	3,225	15	216	325	·590	·0500	Single line. Oilers as above. [Oils mixed.
"	"	228	"	2,732	3,617	6,349	30	216	650	1·181	·0501	2 Lines like above connected. Oils, etc., same.
"	"	342	"	4,098	5,331	9,429	47	216	1,022	1·858	·0552	3 " " " " " "
"	"	16	2⅝ inc.	2,427	2,988	5,415	25	216	378	·687	·0338	Single line, " "
"	"	178	2⅞ "									
"	"	10 ft. 4 in.	4⅛ "									
"	"	80	2⅝ "									
"	"	32	2⅝ "	3,910	5,393	9,303	26	210	873	1·587	·0334	Single line, Oils, etc,, same.
"	"	48	2⅝ "									
"	"	32	2⅝ "									
July, 1871	"	10	2⅝ "									ORDINARY OILING.
"	"	48	2⅝ "	1,289	1,456	2,745	12	150	275	·499	·0340	Single line. Oiled in ordinary way, daily. Tallow
"	"	32	2⅝ "									in Boxes, as safeguard in case of Heating.
"	"	Similar line		1,006		2,295	12	150	217	·394	·0310	" " " "
"	"	34	2⅝ "									
"	"	32	2⅝ "	1,484	1,736	3,220	13	150	291	·537	·059	" " " "
"	"	32	2⅝ "									
"	"	10 ft. 4 in.	2⅝ "									
"	"	176	2⅝ "	2,336	2,999	5,335	24	211	793	1·442	·0759	Single line. Had been oiled A. M., test at 11 A. M.
"	"	Similar line		2,336	2,999	5,335	24	211	679	1·234	0·650	" " Taken just after oiling.
Jan., 1872	Whittenton Mills	About 200 ft.	2¾ "	2,700*	.....	.....	....	155	314	·571	.....	
Feb., 1872	Langdon "	24 ft. 10 in.	2⅝ "	295	350	645	4	210	143	·260	·114	" " Sprung in centre by pull of Belt.
Mar., 1872	Haydensville,	42	2⅝ "	428	.....	.....	5	120	147	·267	.....	
April 1, '72	Salmon Falls, N. H.,	9	4 "	3,151	2,354	5,805	31	211	857	1·558	·0714	" " Tallow in Boxes, taken at noon; had been oiled early in A. M.
April 2, '72	"	231	2¾ "									
		Same shaft.		3,151	2,354	5,805	31	211	619	1·120	·0516	Tallow removed from Boxes, and sponge satu-
May, 1872.	Rockport, Mass.	9 ft. 10 in.	3 "									rated in oil substituted. Time of testing as before.
"	"	32	2⅝ "									
"	"	32	2⅝ "	1,987	2,000*	3,987	30	185	376	·685	·0568	Oiled daily in usual manner.
		96	1⅞ "									
May, 1872.	Masconom't M'l	10 ft. 8 in.	3 "									
	Newburyport,	24	2¼ "									
		127 ft. 1 in.	2⅝ "	3,554	4,268	7,882	37	245	1,628	1·870	·0585	" " " "
		64	2 "									
		64 ft. 3 in.	1¾ "									
Nov., 1872.	Paterson, N. J.,	100	1⅞ "	unkn'wn	unkn'wn	unkn'wn	11	170	184	·335	.....	Dreyfuss Oilers.
Nov., 1873.	Granite Mills, Fall River.	About 200 ft.	2 "	"	"	"	....	200	302	·549	.....	" "

*Estimated.

AN ACCOUNT OF AN EXPLOSION OF A LOCOMOTIVE BOILER.

By Chief Engineer B. F. Isherwood, U. S. Navy.

In January, 1873, the boiler of a locomotive belonging to the "North Pennsylvania Railroad" exploded while the engine stood at the depot awaiting the time to start with a train.

This boiler was constructed of excellent material and workmanship by the "Baldwin Locomotive Works," in January, 1869, and was, consequently, about four years old. Its cylindrical shell was 4 feet in diameter, and composed of 5-16ths of an inch thick steel plates, the longitudinal seams only of which were double-riveted with $\frac{5}{8}$ths of an inch diameter rivets, the cross seams being single-riveted. The length of the fire-box—measured to the tube-plate—was 11 feet, and its breadth was 2 feet and 10 inches. The cylindrical shell contained one hundred and thirty-six tubes of $1\frac{1}{2}$ inch diameter.

At the moment of the explosion, the boiler was well filled with water; its steam-gauge showed a pressure of 100 pounds per square inch above the atmosphere, and the blower was in operation to increase that pressure to 120 pounds before starting. The fireman, who was watching the gauge in order to stop the blower as soon as the latter pressure was attained, escaped uninjured; but the engineer, who was standing by the side of the locomotive, oiling its machinery, was thrown down by the explosion and remained for some time insensible, receiving, however, no permanent injury.

The rupture took place near the middle of the cylindrical shell, and in one plate only, which was fractured through the solid metal successively on opposite sides of the shell and a little below the horizontal plane passing through its axis.

These fractures were nearly in straight lines horizontally, and the two edges of the remaining part of the broken plate were bent over outwards. On both sides of the shell, the fractures extended the whole length of the plate up to the two cross seams, one at each end, which united it to the adjacent plates. These cross seams were also ruptured, but only above the horizontal fractures, and must have given way in the interval of time between the two longitudinal fracturings, and their yielding was partly through the solid metal of the plate, partly through the line of rivet holes, and partly through the shorn rivets. The portion of the plate thus blown out had the shape originally of a vault whose cross section was a little more than a semi-

circle of 4 feet in diameter, and whose length was the distance between the two cross seams, one at each end, joining it longitudinally to the adjacent plates: if flattened, this vault-shaped piece would have formed nearly a perfect parallelogram. It was hurled by the explosion about 400 feet horizontally and with such violence that it passed first through the front and rear walls of a brick house about 200 feet distant, and then through a brick wall situate about 200 feet further on. The entire front of the house was daubed and stained with the muddy water of the boiler. The feed-pipe, which was attached to the ruptured plate at one of its horizontal lines of rupture, was broken off and thrown in an opposite direction, killing a man and boy who were standing about 250 feet from the boiler. The steam-pipe (about 6 inches diameter) and all the tubes except those of the two lower rows, were completely collapsed, torn from their plates, and bent or bowed out toward the opening made by the explosion, but not ejected from the shell. The tubes of the two lower rows remained intact; the locomotive stood unmoved on the rails, and no other portions of it were injured in the least degree than those above mentioned.

At the lines of longitudinal fracture, the plate was found to have been cracked along its whole length, previously to the explosion, to the depth of 4-16ths of an inch, leaving only 1-16th of an inch of solid metal to sustain the pressure of the steam, instead of the 5-16ths of an inch that the plate possessed at all other parts. Thus the pressure in the boiler of 100 pounds of steam per square inch, was opposed by 1-16th of an inch thickness of metal on each side, or $\frac{1}{8}$th of an inch in the aggregate, making the strain on the metal per square inch of its section ($\frac{48\times100\times1}{0.125\times1}$=) 38,400 pounds supposing no assistance to have been derived from the riveting of the ruptured plate to the adjacent ones; and less than that to the extent of any such assistance.

All the facts of this explosion are well ascertained. They are:—

1st. The exploding steam-pressure was 100 pounds per square inch above the atmosphere, up to which it had been gradually raised.

2d. The boiler was well filled with water.

3d. The locomotive was standing motionless on the rails.

4th. One of the plates of the cylindrical shell was cracked horizontally along its whole length and on both sides of the shell, reducing the original thickness of the metal, at nearly diametrically opposite sides of the shell, four-fifths. The plate had apparently been in this state for a considerable time before the explosion.

5th. Under these conditions fracture occurred along the two cracks, and, at right angles to them, along that part of the two cross seams lying above the cracks. These cross seams joined the cracked plate to the adjacent ones. The broken out piece of plate being the upper half of the cylindrical shell for the length of the fractured plate, formed, when flattened, nearly a perfect parallelogram. The fracture along the cross seams, was partly through the full thickness of the plate, partly through the line of the centres of the rivet-holes, and partly through the shorn off rivets.

6th. Nearly all of the water together with its contained mud, was projected from the boiler and thrown to a considerable height, scattering widely right and left as it fell.

7th. The broken out piece of plate was thrown at a small angle above the horizon; and both the horizontal edges of the remaining part of the plate were curved over and outwards.

8th. The steam-pipe, and all the tubes with the exception of those of the two lower rows, were collapsed, torn from their plates and bowed toward the large opening made in the top of the shell by the explosion, but none were thrown out of the shell.

9th. No damage other than what has been described, was done by the explosion to the locomotive, which remained throughout motionless upon the rails.

10th. The metal yielded under a tensile strain of only about 38,400 pounds per square inch of its section.

It is probable that the shell first gave way at one of the cracks and along the whole length of the cracked plate; that the broken out piece of metal was then torn or rather shorn along the two cross seams, flattening as it proceeded, until the crack on the opposite side of the shell was reached, when the metal there gave way under the combined tensile and transverse strains brought upon it, and the detached piece was hurled with great violence in a direction slightly inclined above the horizon.

Through the opening thus made in the top of the shell, nearly all the water in the boiler was projected to a considerable distance, and with such force as to collapse the tubes, tear them from their plates, and bend them in the direction of the opening, but not with sufficient force to drive them through that opening. This water spreading as it left the boiler, probably beat out or curved over the two horizontal edges of the remaining portions of the fractured plate.

This explosion is an illustration of what occurs in a boiler contain-

ing water and a rapidly but continuously increasing steam-pressure when a large portion of its shell is so weakened by cracks nearly through the plate and of such form as to enclose a piece of metal which may be considered as a very large *unweighted* safety-valve *stuck* to its seat and, consequently yielding *suddenly* and *completely* when the pressure rises sufficiently to overcome the sticking. The difference between this case and that of a safety-valve consists in this: that the latter is *weighted*, and the cracked-around piece of the metal is *unweighted*. The safety-valve opens when the pressure to which it is weighted is attained, and permits the gradual escape of any steam additionally generated, but retains the pressure for which it was weighted within the boiler, consequently, any projection of water from the boiler is impossible, because the constant pressure maintained upon the water is that which is normal to its temperature; but, if the safety-valve be supposed unweighted, and held in its seat only by adhesion, then, when the pressure rises sufficiently to overcome that adhesion, the valve will be blown from its seat with great velocity, and the opening, if large enough, so produced in the shell will discharge all the steam at once, reducing the pressure to that of the atmosphere, while the water having the temperature normal to the pressure of the steam before its sudden discharge, will, under the reduced pressure, be set into violent ebullition and projected with great force along with and by the steam thus simultaneously generated throughout its entire mass. This would be an exact reproduction of the phenomena of the explosion above narrated, with an opening of the size of that in the exploded boiler, and with an equal steam-pressure. It shows that a true explosion with much destruction may result from a boiler having a weak spot, if this spot be sufficiently large, while all other parts have ample strength, instead of a mere rupture at this weak spot accompanied by a harmless discharge of steam as in the case of a safety-valve. Of course, the destructive effect will be in proportion to the pressure of the steam at the moment of the explosion.

It is probable that the metal was not ruptured wholly by the tensile strain of 38,400 pounds per square inch of section, but was cracked a few moments before the explosion still more deeply than the quarter of an inch shown at the blackened edges, and which was evidently of long standing, by buckling under the rapidly changing temperature due to the rapidly increasing steam-pressure, an effect to which a brittle material like steel is always liable.

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THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. RICHARDS, Mechanical Engineer.

[Continued from Vol. lxviii, page 206.]

Aside from the greater rapidity with which a hammer may operate when working on this principle, there is nothing gained and much lost; and as this kind of action is imperative in any hammer that has a "maintained connection" between its reciprocating parts and the valve, it is perhaps fair to infer that the reason why most automatic hammers act with an elastic blow is either from a want of knowledge as to a proper valve arrangement, or because of mechanical difficulties in arranging valve gear.

In working with dead blows no steam is admitted under the piston until the hammer has finished its down stroke, and expended its momentum upon the work. So different is the effect of these two plans of operating, that on most kinds of work a fifty pound hammer working with dead blows, will perform the same duty that one of a hundred pounds will, when acting with elastic or cushioned blows.

This difference between the dead and elastic stroke is so important that it has served to keep the hand moved valves in use in many cases where much could be gained by automatic hammers that had the same functions.

Some of the makers of steam hammers have now so perfected the automatic class, that they may be instantly changed so as to work with either the dead blow or the elastic blow at pleasure, thereby combining all the advantages of both principles. This brings the steam hammer where it is hard to imagine a want of farther improvement.

The valve gear of automatic steam hammers to fill the two conditions of allowing a dead or an elastic blow, furnishes one of the most interesting examples of mechanical combination.

It was stated that to give a dead or stamp stroke, the valve must move and admit steam beneath the piston after the hammer has made the blow, and stopped on the work, and that such a movement of the valve could not be imparted by any maintained connection between the hammer-head and valve. This problem is met by connecting the

drop or hammer-head with mechanism that will by reason of its momentum, continue to "move after the hammer-head stops." This mechanism may consist of various devices. Messrs. Massey in England, and Messrs. Ferris & Miles in America, employ a swinging wiper bar that is by reason of its weight or inertia, retarded and does not follow the head closely on the down stroke, but swings into contact and opens the valve after the hammer has come to a full stop.

By holding this wiper bar continuously in contact with the hammer drop, elastic or rebounding blows are given, and by adding weight in certain positions to the wiper bar, its motion is so retarded that the hammer will act as a stamp or drop. A German firm employs the concussion of the blow to disengage the valve gear, and effect this after movement of the valves in steam hammers. Other makers effect the same end by employing the momentum of the valve itself, by having it connected to the drop by a slotted or yielding connection, that allows an independent movement of the valve to a certain extent.

COMPOUND HAMMERS.

Another principle to be noticed in connection with hammer action in forging processes is that of the inertia of the piece operated upon, a matter of no little importance in the heavier class of work.

When a piece is placed on an anvil and struck on the top side with a force of one ton, the bottom or anvil side of the piece does not receive an equal force. A share of the blow is absorbed by the inertia of the piece, and the effect on the bottom side is, theoretically, directly as the force of the blow, less the inertia of the pieces acted upon.

In practice this difference of effect on the top and the bottom, or between the anvil and the hammer sides of the iron, is much greater than would be supposed. The yielding of the soft metal on the top cushions the blow and protects the under side from the force; this, because the effect produced in striking a piece of heated iron is by no means to be measured by the force of the blow. It requires, to use a technical term, a certain amount of force to "start" the iron, and anything less than this force has but little effect in starting the particles and changing the form of the piece.

From this the apprentice can see that there must occur a great loss of power, for whatever force is absorbed by the weight of the piece produces no effect. By watching a smith using a hand hammer it will be seen that whenever the piece operated upon is heavier than

the hammer, but little if any effect is produced on the anvil or bottom surface. Nor is this loss of effect the only one. The cost of heating, which generally exceeds the cost of shaping, is directly as the amount of shaping that may be done at each heat; and consequently if the two sides of a piece, instead of one, can be equally acted upon in shaping, one-half the heating will be saved.

Another consideration to be gained by equal action on both sides of large pieces is the quality of the forgings produced, which is generally improved both by the rapidity of the shaping processes, and injured by too frequent heating.

This loss of effect by the inertia of the piece acted upon being as the relative weight of the hammer and the piece, it follows that the loss increases with the weight of the work; not only the loss of power, but the cost of heating, which also increases with the size of the work. There is such a difference in the mechanical conditions between light and heavy forging that for any but heavy work there would be more lost than gained in attempting to evade or remedy this loss of effect on the anvil face of the work.

To remedy this defect in heavy forging, Mr. Ramsbottom, C. E., designed what I have termed compound hammers, consisting of two independent heads or rams moving in opposite directions, and acting simultaneously upon the work which is held between them.

These hammers of Mr. Ramsbottom were a departure from all modes of forging that had ever been practiced to the time, and constituted an original invention; one that has fully attested its value in actual service at Crewe, England, where such hammers have been at work for several years.

It will seem probable that the arrangement of these double acting hammers is necessarily complicated and expensive, but the contrary is the fact. The rams are simply two masses of iron mounted on wheels that run on tracks like a truck, and the impact of each hammer, so far as not absorbed in the work, is neutralized by the other. No shock or jar is communicated to framing or foundations as in the case of single acting hammers that have fixed anvils. The same rule applies in the back stroke of the hammers, as the links that move them are connected together at the centre, where the power is applied at right angles to the line of the hammer movement. The links connecting the two hammers constitutes, in effect, a toggle joint, the steam piston being attached when the links meet in the centre.

The steam cylinder is set at some depth in the earth below the plane upon which the hammers move, and even when the heaviest work is done there is no perceptible jar to be felt when standing near the hammers, as there always is with those that have vertical movement and are single acting.

The apprentice is recommended to procure and study drawings of these hammers as a most interesting example of modern engineering practice.

As drops bear a close analogy to steam hammers and press forging, not used to any extent in machine shops, it will hardly be worth while to devote any space to forging machinery of this class. The purpose being to treat of what the apprentice will meet in the smith's shop and to confine explanation so far as possible to what is in common use.

TEMPERING STEEL.

Tempering is the romance of the smith's shop, it has an attraction about it that characterizes every process that is mysterious, especially any process connected with, or belonging to mechanical manipulation. A strange and perhaps fortunate habit of mind is to be greatly interested in what is not understood, and to disregard what is capable of plain demonstration.

An old smith who has stood at the forge for a score of years, will take almost the same interest in tempering processes that a novice will. Give an old smith a piece to temper that is liable to spring or break when the risk is great, and he will enter upon it with the same zeal and interest that he would have done when learning his trade.

No one has been able to explain why a sudden change of temperature hardens steel, nor why it assumes various shades of color at different degrees of hardness; even the most critical researches into the chemistry of steel has offered no rational explanation. We only know the fact, and that fortunately steel has such properties. Every one that uses tools should understand tempering them, whether it be for iron or wood work. Experiments with tempered tools is the only means of determining the proper degree of hardness, and as smiths except with their own tools have to rely upon the explanations of others as to proper hardening, it follows that tempering is generally a source of complaint with those who use tools hardened by others.

Tempering, which as a term, is used to comprehend both hardening and drawing, is almost solely a matter of judgment, instead of skill, and has no such intimate connection with forging as to be per-

formed by smiths alone. In fact it requires a different kind of fire from those used in forging, and also requires as a process more care and precision than blacksmiths usually exercise in their operations, unless they have furnaces and baths especially arranged for tempering tools.

A difficulty that arises in hardening is from the contraction of the steel which takes place in proportion to the change of temperature; and as the time of cooling is in proportion to the section of a piece, it follows of course, that there is a great strain and a tendency to break the thinner parts before the larger parts have time to cool and contract, or this strain may take place from the cooling of one side first, or more rapidly than another.

The following propositions in regard to tempering, comprehend the main principles to be observed:

The permanent contraction of the steel is as the degree of hardness that is imparted to it by the bath.

The time in which the contraction takes place is as the cross section of the piece at any part; or in other words the heat passes off first from the surface, and then uniformly from the surface to the centre.

The thin sections of steel tools being removed from or projecting from the mass which supports the edges are cooled first, and if provision is not made to allow for contraction, the thin sections or edges are torn asunder.

The main point in hardening and the most that can be done to avoid irregular contraction, is to apply the bath so that it will act first and strongest on the thickest part. If a piece is tapering or in the form of a wedge, the thick end should enter the bath first; a cold chisel for instance that is wide enough to endanger cracking should be put into the bath with the head downward.

The upflow of currents of warmed water are a common cause of irregular cooling and the springing of steel tools in hardening; the water that is heated, rises vertically, and the least inclination of a piece from a perpendicular position, allows this warm current to flow up on one side and to leave the piece on the other.

The most effectual means of securing uniform effect from the bath is by violent agitation, either of the bath or the piece; this also adds to the rapidity of the cooling.

The effect of tempering baths is as their conducting power; chemical effect need not be considered except as it may contribute to this.

For baths, cold water or ice water loaded with salt and warm oil, are the two extremes outside of which nothing is required.

In tools composed partly of iron and partly of steel, steel laid as it is called, the tendency to crack in hardening may be avoided in a great degree by hammer-stretching, hammering the steel edge at a low temperature until it is expanded so that when cooled in hardening it will only contract to a state of rest with regard to the iron parts; the same effect can be produced by curving a piece, giving convexity to the steel side before hardening.

Tools should never be tempered by immersing their edges or cutting parts in the bath, and then allowing the heat to "run down" to do the tempering. I am well aware that this is attacking a general custom, but it is none the less wrong for that reason.

Tools so hardened have a gradually diminishing temper from their point or edge, so that no part is properly tempered, and they require continual re-hardening, which spoils the steel; besides the extreme edge is usually spoiled and must be ground away to begin with. No latheman who has once had a set of tools tempered throughout by slow drawing, either in an oven, or on a hot plate, will ever consent to point hardening afterwards. A plate of iron, two to two and one-half inches thick, placed over the top of a tool dressing fire, makes a convenient place for drawing temper, besides adding greatly to the convenience of slow heating, which is almost as important as slow drawing. The writer has in one case by actual experiment determined that the amount of tool dressing and tempering, to say nothing of time wasted, was in ordinary machine fitting, reduced more than one-third by "oven tempering," the tools for lathes and planing machines.

As to the shades that appear in drawing temper, or tempering it is sometimes called, it is quite useless to repeat any of the old rules about "steam color, violet, orange, blue," and so on, the learner knows as much after such instruction as before. The shades of temper must be seen to be learned, and as no one is likely to have use for the knowledge before having opportunities to see tempering done, I will recommend the following plan which will be found an efficient one to begin with, in learning the shades of temper: Procure 8 pieces of cast steel about two inches long by one inch wide and three-eighths of an inch thick, heat them to a high red heat and drop them into a salt bath, leave one without tempering to show the white shade of extreme hardness, and grind off and polish one side of each of the

remaining seven pieces; then give them to an experienced tool maker to be drawn to seven various shades of temper ranging from the white piece to the dark blue color of the soft steel. On the backs of these pieces paste labels describing the technical name of the shades and the general uses to which tools of corresponding hardness are adapted.

This will form an interesting collection of specimens, and accustom the eye to the various tints, which will after some experience be instantly recognized when seen separately.

It may be remarked as a general rule the hardness of cutting tools is "inversely as the hardness of the material to be cut," which seems anomalous and no doubt is so if nothing but the edge is to be considered; but all edges are subjected to transverse strain and this transverse strain is constantly as the hardness of the material acted upon; hence the degree of temper has of necessity to be such as to guard against breaking. Tools for cutting wood for example can be much harder than for cutting iron, or to state it better, tools for cutting wood are harder than those usually employed for cutting iron, for if iron tools were always as carefully formed and as carefully used as wood tools are, they could and should be equally hard.

Forges, pneumatic operators for blast machinery for handling large pieces, and other details connected with forging, are easily understood from examples, and if treated of here would exclude other matters of greater interest to the apprentice.

FITTING AND FINISHING.

Fitting and finishing as a department of Engineering establishments is generally regarded as the main one.

These processes, being the final ones in constructing machinery, are more nearly in connection with its use and application, and besides consists in the organization, or bringing together the results of other processes, carried on in the drafting and pattern shops, the foundry and smith-shop.

To those who are unskilled, or who do not take a comprehensive view of engineering business as a whole, the finishing and fitting seems to constitute the whole of machine manufacture, an impression that the apprentices are especially to guard against, because nothing but a true understanding of the importance and relations of the different divisions of such can enable them to be thoroughly or easily learned.

In treating of finishing, therefore, the reader must consider it as one among several processes, as one out of at least four departments among which his attention is to be divided.

Finishing as a process is a secondary and not always an essential one; many parts of machinery are ready for use when they are forged or cast and do not require finishing; yet finishing must in many respects be considered the leading department of engineering establishments.

Plans, drawings and estimates are always based on the finished machinery; upon this result often it is organized, and when the parts have accurate dimensions; hence designs, drawings and estimates must first pass through the fitting shop and follow back to the foundry and smith shop, so that finishing, although the last process in the order of the work, is the first after drawing in every other sense; even pattern making which seems farthest removed from finishing, must be based upon the finishing dimensions, and to a great extent remodified by the conditions of fitting and finishing.

In casting and forging as preliminary operations the material is treated while in a heated and expanded condition. Besides the nature of these operations does not admit of testing dimensions with accuracy, so that forgings and castings require to be made enough larger than their finished dimensions to allow for irregularities and shrinkage.

Finishing as a process consists in cutting away this surplus material and giving accurate dimensions to the parts of machinery, when the material is at its natural temperature.

Finishing operations being performed as said upon material at its normal temperature permits handling, guaging and fitting together of the parts of machinery, and as nearly all other processes in converting metal involve heating, finishing may be termed the cold processes of metal work.

Finishing processes in metal work consist in cutting, abrading, and handling material. A proposition that may seem novel, yet these operations comprehend nearly all that is performed in a fitting shop.

Cutting processes may be divided into cylindrical cutting as in turning, boring, and drilling, to produce circular forms, plain cutting, as in planing, shaping, slotting and shearing, to produce plain or rectangular forms, and cutting to produce irregular outlines.

Abrading or grinding processes may be applied to forms of any kind.

To classify further—cutting machines may be divided into those wherein the tools move and the material is fixed, and those wherein the material is moved and the tool fixed, or, machines that involve a compound movement of both the tools and the material acted upon.

There is also the distinction between machine and hand cutting that may be noted. In the first the cutting is done in true geometrical lines, the tools or material being moved by positive guides as in planing and turning; in hand operations, such as filing, scraping or chipping, the tools are moved without positive guidance, and act in irregular lines.

To attempt the generalization of the operations of the fitting shop in this manner may not strike the reader as a very practical means of understanding them, yet the application can be seen as we go farther on.

Tools directed to cutting include nearly all that are used in finishing operations, such as lathes, planing machines, drilling and boring machines, shaping, slotting and milling machines, and so on. These make up what is called standard tools, such as are essential and are found in all establishments where a full line of machine manufacture is carried on, and are constructed upon principles that are substantially the same in all countries at this day.

Besides these machine tools there are special machines to be found in most works, machines directed to the performance of some special work, where by a particular adaptation they are rendered more effective, but are, at the same time, unfitted for general use or to perform more than one function.

Engineering work cannot to any extent consist in the production of duplicate pieces, nor in operations that are constantly performed in the same manner as in ordinary manufacturing; hence there has been much effort expended in the adaptation of machines to general uses, machines that have not always avoided the objections of combining several functions in one, yet, upon the whole, machine tools may safely be regarded as the most perfect, and as having undergone the least change of any class of machines during twenty years past.

This general adaptation and certain standard forms of constructing machine tools enables their manufacture to be carried on as a regular branch.

The greatest improvement and change going on in machine fitting at the present time is in the adaptation of special tools. A lathe, a planing machine or drilling machine as standard machines must be adopted to a certain range of make, but it is evident that if such tools were specially arranged for either the largest or the smallest pieces that come within their capacity, more work could be performed in a given time and consequently done cheaper than on a standard machine; it is also considered that machine tools must be kept constantly at work in order to earn money, and when there are not sufficient pieces of one size to occupy a machine, the machine must do two or more sizes; but whenever there are sufficient pieces of a uniform size and certain processes of a uniform character to perform, there is a gain in having machines constructed to conform as nearly as possible to the requirements of special work, and without reference to any other.

This is in brief some of the principles that apply to special, as distinguished from general operations in machine fitting, and to which the attention of the apprentice is called as one of the important conditions connected with modern shop manipulations.

It is now proposed to review the standard tools of the fitting shop, the general principles of their construction and especially of their operation; not by drawings nor descriptions to show what a lathe or a planing machine is, nor how some particular tool builder has constructed them, but upon the plan explained in the introduction, presuming that the reader has seen and knows the names of standard machine tools, and has already learned such things at least as may be observed or understood by the unskilled.

If the reader has not learned this much and does not understand the names and general objects of the several operations carried on in the fitting shop, he should proceed to acquaint himself this far by personal observation and inquiries before troubling himself with books of any kind.

(To be continued.)

Chemistry, Physics, Technology, etc.

THE SPECTROSCOPE IN ITS APPLICATION TO MINT ASSAYING.

By Alexander E. Outerbridge, Jr.

The invention of the simple instrument called the Spectroscope has led, within a brief period of years, to such astounding revelations that it is not unnatural to imagine that untold possibilities may still lie concealed in its future. Those who are at all familiar with the subject of spectrum analysis, do not require to be told that the spectroscope has increased ten-fold the range of human knowledge within the domain to which it is applicable; and has also reduced much of what has heretofore been little better than matter of speculation, to a certainty as convincing, to a scientific mind, as a mathematical demonstration. Applicable alike to the analysis of tangible substances and of the celestial fires, its mysteries have been wrested from it, as it were, from an invisible world, by its devoted students.

All the classes of observations hitherto accomplished, fall under the head of *qualitative* analysis, in which perfection appears to have been already attained. Should a like perfection be attainable *quantitatively*, little more would appear desirable. With the view of probing for new facts in this direction, a limited but promising field of experiment has lately been adopted simultaneously, but independently, in the assay departments of the Royal Mint in England, and of the U. S. Mint at Philadelphia, and the attempt has been made to insert the wedge of future investigation by obtaining from the spectroscope a quantitative analysis of the composition of metallic alloys.

In a late annual report of the Royal Mint, Mr. Wm. Chandler Roberts, the chemist of the Mint (who with Mr. J. Norman Lockyer, the pioneer in Spectroscopic research, has been conducting a series of experiments), states he is satisfied that by means of the Spectroscope very minute differences in composition of gold-copper alloys can be ascertained. He, however, "refrains from describing the process, as the exact method of manipulation had not been determined upon." In the following pages the attempt is made to narrate, not technically, the process adopted and the conclusion arrived at in the experiments made in Philadelphia, the details of which are contained in a report by the writer to the chief assayer of the Mint, dated May, 1874, and published in the Proceedings of the American Philosophical Society of the 15th of that month, Vol. xiv, page 162.

The beautiful party-colored band of light, resembling a section of a miniature rainbow, resulting from the passage of a ray of white light through a prism, is familiar to every one; this simple experiment forms an appropriate introduction to the fascinating study of Spectrum Analysis.

Every kind of light not strictly mono-chromatic may, by means of the prism, be resolved into its component colors. The Spectroscope is a simple combination of prisms and lenses for the scientific examination of these different colors or spectra.

The numerous terrestrial elements, when in the state of incandescent vapor, give their own distinctive colors, which appear in the Spectroscope as *lines of light* arranged in definite positions, whereby each element may be easily recognized.

The passage of powerful electric sparks (from an induction coil) between two terminal points of the metal to be examined, vaporizes a small portion of the metal, and this incandescent vapor transmits to the eye of the spectroscopic observer its *luminous autograph* which nature never counterfeits. Should either or both of the metallic points, or *electrodes*, consist of an alloy of two or more metals, the autograph of each may be clearly read.

Mr. Lockyer noticed, while studying these luminous autographs, that when he separated the metallic electrodes, causing the spark to leap a greater distance through the air, the spectral lines no longer continued to cross the entire field of vision but certain of them *broke in the middle*, and upon further increasing the distance between the electrodes, the hiatuses in the spectral lines increased proportionately, *but unequally with different alloys*. As the proportion of either metal of an alloy is increased, *its lines lengthen* and conversely with the lines of the other metal. Upon this discovery, Mr. Lockyer based the theory of a possible method of quantitative analysis.

The Spectroscope was known to be marvellously sensitive to the impression of these autographs, and it therefore appeared plain, that could such a method of analysis be reduced to a practical basis, its value would be immense in assaying metals used in coinage. For although the present modes of assaying precious metals have been brought to great perfection, yet the process is slow and tedious, requiring many chemical operations and great delicacy of manipulation; and "there is something captivating in the idea of a determination, as it were, by a flash of lightning or in the twinkling of an eye, what proportion of gold or silver is present in any bar or coin."

It was with the hope of reducing this beautiful theory of Mr. Lockyer to practice that these experiments were undertaken. The investigation extended over a period of several months, the principal part of the work being conducted at the University of Pennsylvania, with the benefit of the excellent apparatus and appliances afforded in the new college building: a privilege kindly extended by Professor Barker of that institution.

A powerful induction coil, reinforced by Leyden jars, in connection with a two prism Browning spectroscope was employed, and it was found possible after repeated comparisons of the spectra of different known alloys of gold and copper to map the difference of fineness between specimens having respectively 500 and 750 parts of gold in 1,000 of the alloy, and even to recognize the variation between coin-ingots 895 and 902 fine. This variation, within seven thousandths, was by no means marked, although it seemed probable that a more delicate adjustment of apparatus and further experience would render the distinction more decided.

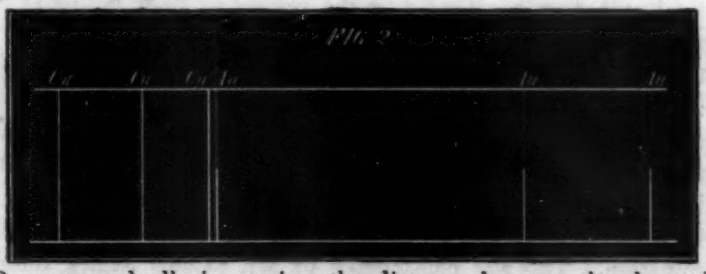
The spark, in passing through the air, also vaporizes its constituents, viz: oxygen, nitrogen, etc.; these of course write *their* signatures in the spectroscope, and it is necessary to eliminate the numerous bright air lines which thus appear in all the spectra. Some of the lines of different metals appear in close proximity and might readily be misinterpreted. Thus a bright blue line of bismuth is almost identical in position with one of zinc. A green line of iron is nearly coincident with a bright gold line. The difficulty which presented itself in the exact comparison of these proximate lines, was overcome by using a pure metal as one electrode and another pure metal as the other electrode. The effect thereby produced was very curious. With pure gold and pure copper as the electrodes, the gold lines extend across only one-half the field of the spectrum, and the copper lines extend across only the other half, the medial termini of both sets of lines being perfectly sharp and bright. By this means a double spectrum of copper and gold is obtained, or rather, a section of a complete gold spectrum and a section of a complete copper spectrum are visible in immediate juxtaposition, thereby enabling a most accurate comparison of lines, which in reality are not identical in position, but which by the previous method were apparently so.

By a slight modification of the experiment, substituting pure copper as one electrode and an alloy of silver and gold as the other, the

proximate lines of these three metals are presented mapped, as it were, on a natural scale. (Fig. 1.)

Further modifications of this principle suggested themselves and were tried with indications of valuable results.

By using as one electrode, an alloy of gold and copper of comparative fineness, and a baser alloy of the same metals as the other electrode, a result not before observed presented itself. The lines of both copper and gold crossed the entire field of vision, but in the section representing the fine alloy, the gold lines were strong and bright, while in the section representing the base alloy the gold lines were very faint. (Fig. 2.)



By now gradually increasing the distance between the electrodes, the faint gold lines of the base alloy cease to join their bright counterparts of the fine metal at the central line. (Fig. 3.)

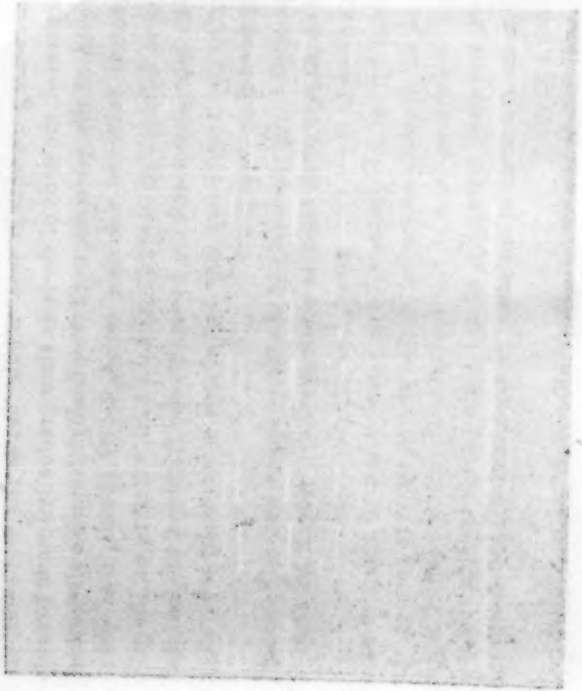
The intervening space is at first minute, but as the electrodes are further separated, the ends of the faint lines gradually recede towards the outer edge of the spectrum, until they finally disappear altogether.

The general principle was thus satisfactorily proved, that where two alloys of different grades are subjected to this treatment, the gold lines of the baser compound are noticeably the fainter of the two, and what is more important, they may be reduced in length by separating the poles, until they disappear.

This pointed to the possibility of the future application of Spectrum Analysis to Assaying, at least as a test method. For, if an alloy of absolute known fineness were adopted as one electrode, and an ingot-slip assayed by the old process to an equal grade of fineness were inserted as the opposite electrode, in case the assay were correct, the gold lines in both sections of the spectrum should appear of equal brightness, and more especially, should begin to recede from the central line of the spectrum at the same moment, and should disappear at the same moment.

The spectra being inevitable natural effects of physical causes, a variation between two specimens of supposed equal fineness would, *in theory*, be necessarily indicated by the respective lines failing to correspond in their reciprocal action.

A serious source of error in these comparisons, was soon discovered, viz: that if one electrode was nearer the centre of the slit of the spectroscope than the other, its spectral lines would appear proportionately longer than those of its *vis-a-vis* even though both electrodes were of the same pure metal. It then became necessary to devise a special apparatus for manipulating the electrodes, when under examination. This was constructed by Mr. Samuel James, the machinist in the Mint, and admirably fulfilled its object. A wood-cut of it is appended hereto. Its peculiarity consisted in an automatic combination of accurately proportioned screws, acting in opposite directions, by which a single motion of the hand sufficed to cause the upper and lower electrodes to approach or recede from the central line of contact in an equal degree. The electrodes, which consisted of small strips of metal cut to a point, were held by a suitable arrangement on the outer circumference of two metallic rings insulated from each other, the upper one slotted to receive a series of twelve electrodes of varying *known* fineness, and revolving horizontally, so that each electrode might in turn be adjusted to face a single electrode of *unknown* fineness fixed on the lower ring. Its object was



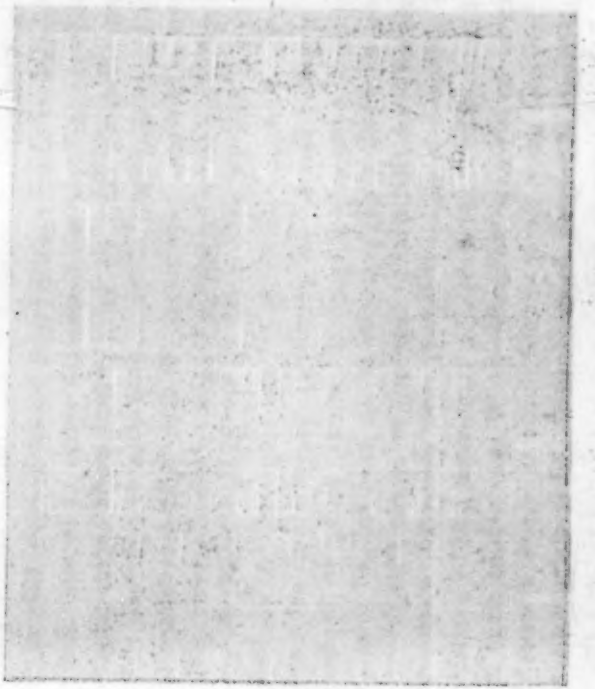


PLATE 1

Spectra of Volatile Metals.

Quantitative Spectra of Gold-Copper Alloy.

[illegible] of the electrodes being separated to [illegible] extent, without crossing the line of vision, through the [illegible], directed to the centre of the spark.

In regulating the height of the instrument, the [illegible] was always obtained by passing the spark between two electrodes of pure gold, so that in separating the points, the respective spectra [illegible] corrected exactly in their reciprocal action.

A systematic series of experiments was now undertaken, in which the behavior of the more volatile metals was [illegible]: Zinc, Bismuth, Tin, Antimony, Cadmium, [illegible].

All these give more detailed spectra than the [illegible] metals, and some interesting results were obtained. A [illegible] illustrations of some of these spectra are appended.

A very curious fact is apparent in all these spectra, viz: the [illegible] *lengths* of the spectral lines. Some of the lines of Bismuth, for example, are seen to extend nearly across the field of vision, while others appear as mere points near the edge. Mr. Lockyer has published some most interesting investigations upon the subject of [illegible] and short lines."

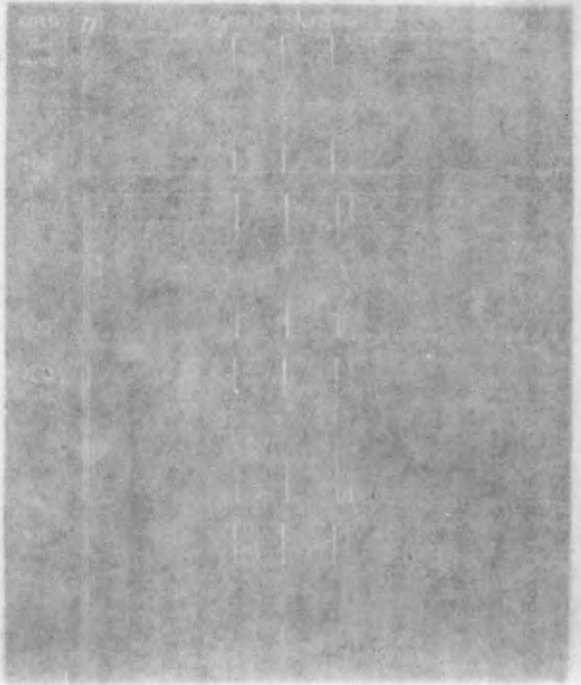
Proceeding to the examination of gold alloys, and starting with [illegible]—making the lower pole [illegible] fine and the upper pole 500 fine—the gold lines from the upper [illegible] were both longer and brighter. Now substituting in place of the [illegible] pole one 750 fine, the lower half showed the brighter gold lines. Then, changing the [illegible] pole for one 900, the brightness of the gold line was again reversed. This alternating effect may be continued, decreasing in degree as the fineness of the poles approach more nearly together, until [illegible] the same fineness, when the lines will be equal in [illegible]. These experiments proved satisfactorily that [illegible] variations in the composition of gold alloys were [illegible]. A series of graduated alloys of more approximate fineness [illegible] proposed the Mint, viz:

GOLD AND COPPER.	GOLD, SILVER AND COPPER.
958·	
917·	
900·	
888·8	
888·6	
876·5	

PLATE 1.

Spectra of Volatile Metals.

Quantitative Spectra of Gold-Copper Alloy.



to admit of the electrodes being separated to any desired extent, while preserving the line of vision, through the spectroscope, directed to the centre of the spark.

In regulating the height of the instrument, the apparatus was always adjusted by passing the spark between two electrodes of pure gold, so that, on separating the points, the respective spectral lines corresponded exactly in their reciprocal action.

A systematic series of experiments was now commenced, in which the behavior of the more volatile metals was at first studied, viz: Lead, Zinc, Bismuth, Tin, Antimony, Cadmium, Mercury, Aluminum, etc. All these give more decided spectra than the less volatile precious metals, and some interesting results were noticed. Approximate illustrations of some of these spectra are appended.

A very curious fact is apparent in all these spectra, viz: the *unequal lengths* of the spectral lines. Some of the lines of Bismuth, for example, are seen to extend nearly across the field of vision, while others appear as mere points upon the edge. Mr. Lockyer has published some most interesting investigations upon the subject of these "long and short lines."

Proceeding to the examination of gold alloys, and starting with base poles—making the lower pole 250 fine and the upper pole 500 fine—the gold lines from the upper half were both longer and brighter. Now substituting in place of the 250 pole one 700 fine, the lower half showed the brighter gold lines. Then, changing the 500 pole for one 800, the brightness of the gold line was again reversed. This alternating effect may be continued, decreasing in degree as the fineness of the poles approach more nearly together, until both poles are of the same fineness, when the lines will be equal in length and intensity.

These experiments proved satisfactorily that comparatively wide variations in the composition of gold alloys were discernible. A series of graduated alloys of more approximate fineness, was now prepared at the Mint, viz:

GOLD AND COPPER.	GOLD, SILVER AND COPPER.
938·	940·1
917·	918·7
906·	866·8
888·3	888·
883·5	884·1
876·5	883·

These alloys were carefully prepared and assayed closely.

With one electrode pure gold and the other 938 fine, the difference between the respective spectra was of course very marked, the copper lines appearing in the one and not in the other. Substituting for the pure gold the alloy 876·5, the difference was still very marked, for, although both gold and copper appeared in each, the copper lines were much brighter and somewhat longer in the baser alloy, while the gold lines were brighter and longer in the finer. But on comparing the alloys 876·5 and 883·5, (reducing the variation to seven thousandths) it was both a surprise and disappointment to find the visible difference of result but slightly appreciable. And the same with regard to the alloys of 883·5 and 888·3, and the same with other alloys with equal or less comparative variation of fineness. A variation of one-thousandth, required an effort of the imagination as well as of the eye to detect any difference whatever. And, although the attempt was made to map an apparent difference between alloys varying two-thousandths, it would certainly not have been a safe test on which to base an assay. Frequent repetitions with changes of adjustment were tried, the battery power varying from one to six Bunsen cells, in connection with Leyden jars varying from one very small jar (improvised out of a test-tube) to fifty large jars, representing a metallic superficies of many square feet) with variations of the distance of the electrodes apart, and with and without the use of a condensing lens, but all these failed to give closer results.

It is true, that these changes of conditions produced certain variations in the effects observed—as, for instance, it was noticed that an increase in the Leyden jar surface always lengthened the lines—the distance between the electrodes and all other conditions remaining the same—while a decrease in the condensing surface had an opposite effect. Thus, to take the extreme cases, with the single small Leyden jar above referred to, and one cell of battery, the lines broke when the electrodes were not more than one-sixteenth of an inch apart, and disappeared entirely on separating the points one-eighth of an inch.

With fifty Leyden jars and six cells of battery, it was found impossible to break the lines at all, even by removing the electrodes to the extreme limit of the spark, and in this case new lines also appeared.

Other variations occurred; such as a momentary irregularity in the length and brightness of the lines, under a strong battery power, owing to the unequal action of the spark;—a difference in the action

of the gold lines dependent upon the nature of the alloy, silver tending to lengthen them more than equal admixture of copper;—the length of the lines is also dependent upon the distance between the spark and the slit (when the latter is used without the intervening condensing lens);—moreover, the eye itself is liable to become confused by continued comparisons of very slight differences. The above and other modifications, so far from solving the problem of close work, rather indicated possible sources of error.

Another element of the process suggested itself as likely to render the results uncertain for the practical purpose of assaying, viz: whether the quantity of metal vaporized and giving the spectrum is not too infinitesimal to give safe results for a large melt. This would be affected by the least want of homogeneity in the metal. This is a serious consideration, and with the view partly to search for unknown sources of error and partly to ascertain generally the quantity of metal operated on in a spectroscopic assay, (should that ever be possible) the following experiment was tried: Having weighed small electrodes, averaging 18 milligrammes each, with the greatest possible accuracy on the gold assay balance of the Mint, (which is sensitive to a twentieth of a milligramme, or even less,) and having arranged a spark register, it was found that 1000 sparks might be passed between these poles, each spark showing the spectrum of the metal distinctly, and yet the loss in weight was too small to be made the base of calculation. Thus, a gold pole lost in weight after passing 1000 sparks, one-thousandth of a grain; this gives for each spark 1-1000000th of a grain of gold, producing a bright spectrum. The number was then increased to 3000 sparks as a test. The loss of weight depends of course upon the electric volume, and in the experiments tabulated, an endeavor was made to keep the latter constant. A slight deposit of the vaporized metal from the opposite pole takes place in fine division, but this is easily removed—in the case of copper and gold poles by dipping the gold for a moment in weak acid, or by gentle rubbing. The annexed tables (marked A and B) show that the loss in weight is marvelously small, averaging less than seven-tenths of a milligramme of gold for 3000 sparks. To give the amount for each spark, this must be divided by the number of sparks; thus, in round numbers an electrode loses one-thousandth of a grain after passing 3000 sparks; or for 1000 sparks one three-thousandth of a grain, or for each spark 1-1000000th of a grain. The exceedingly small quantity of metal thus assayed renders this process, in the writer's

opinion, inapplicable to the operations in the Mint; for it is necessary to determine gold assays to the one ten-thousandth part of the normal assay weight and it is hardly conceivable that a discrimination to the one ten-thousandth part of the spark assay weight, or the 1-10000000000th of a grain is practically possible. Even if it were, it would not be proper to assume that a test on such an atomic scale would correctly represent the value of a large deposit, or even of gold ingots. It would certainly not be in the case of silver, which segregates.

The experiments made by Cappel to determine the *minimum* amount of each element that will show a spectrum have been published in tabular form. His method was to volatilize "solutions of the metallic salts between the poles of a small induction coil in Mitscherlich's glass tubes with platinum wicks. A series of solutions, each one half the strength of the preceding one, were prepared from a number of metallic chlorides. The spectrum in connection with the positive pole was continually observed while increasingly concentrated solutions were brought in succession into the action of the spark until the lines of the substance were clearly visible." If a sceptical mind refuses to believe the results of Cappel, who tells us that one six hundredth of a milligramme (1-38800th of a grain) of nickel will *just* write the signature of that metal, what will he say when glancing at table B, appended hereto, he finds the statement that one sixty thousandth of a milligramme (1-3880000th of a grain) of nickel will sign its name *in brilliant characters?* And yet the author does not hesitate to say that even a *smaller* amount of this metal will show a spectrum, for it must be remembered that in these experiments a much stronger spark was used than was necessary to show a visible spectrum. When reduced to a minimum, as was done in the case of the miniature Leyden jar, which still gave a distinct spectrum, the loss in weight after 3000 sparks, for silver, copper and tin, was *absolutely inappreciable* on the balance.

The table of loss shows another curious and unexpected result, viz: that the loss in weight of the volatile metals very slightly exceeds and in some cases does not equal the loss of the less volatile metals. Thus, in three different experiments of 3000 sparks each, copper loses but ·1 mgr. while gold loses ·5 mgr.

An unexplained anomaly was also noticed in relation to the sensitiveness of the spectroscope to the metals present in small proportion. Although Mr. Cappel has shown that 1-4000th of a milligramme of gold will show a spectrum (it is even less than 1-6000th of a mgr. according to an experiment performed by the method described above) yet a com-

paratively large proportion of gold may be present in an *alloy*, the presence of which will not be indicated at all by the spectroscope.

In a slip composed thus: Silver, 708 parts; Copper, 254 parts; Gold, 38 parts; the spectra of *silver* and *copper* are alone visible.

In fact, in a base alloy of gold and copper containing from 20 to 25 per cent. of gold, the gold spectrum is barely visible; while in a fine alloy of gold and copper it was found that one per cent. of the latter suffices to show the copper spectrum. Also in an alloy of nickel and copper containing 25 per cent. of nickel its spectrum is scarcely visible. It seems evident therefore, that the spark selects the more volatile metal as its vehicle.

If the spectroscope fails to reveal the presence of anything less than 200 parts of gold in a base alloy, even a theorist must admit that one could scarcely expect to be able to discriminate with certainty a variation of 1-10000th in a fine alloy.

For the foregoing reasons, the conclusion seems inevitable, that in the state of spectroscopic science as it now exists, assaying by means of spectrum analysis is, for the present, impracticable for the purpose of Mint operations.

Although these experiments have resulted negatively from the utilitarian standpoint from which they were undertaken, it is hoped that they may prove not altogether without value in a more general point of view. The fact that quantitative proportions of composite substances may be recognized at all, even to a rough degree, cannot but be regarded as a first step. All observations bearing upon the action of the spectral lines in indicating such proportions are at least worthy of being recorded. Not the least curious of these incidental observations is the fact that while the Spectroscope is sensitive to the minutest fraction of a grain of gold in the pure state or in solution, it fails to reveal the presence of a much larger proportion in a base alloy. Another is the fact that while the spark appears to select for its vehicle of transmission the more volatile metal in an alloy and would thus seem to vaporize a greater quantity of the volatile than of the non-volatile component, yet in point of fact the loss of weight by such volatilization is in some instances much less in the former case than in the latter.

The rationale of these apparent paradoxes is not at present evident, but if we may judge by former experiences in which problems even more mysterious, have been resolved by study, we are warranted in anticipating that when a large number of observations, to be made

perhaps by many experimenters groping in the dark, shall be collated, the true scent may of a sudden be struck which shall discover the desideratum of quantitative spectrum analysis.

TABLES.

The *first* column shows the weight of the metallic electrodes in milligrammes, before passing the sparks. *Second* column shows the weight after passing 3000 sparks. *Third* column shows the *total* weight of metal volatilized (in fractions of a milligramme). *Fourth* column shows the amount of metal volatilized by *each* spark (in fractions of a milligramme). *Fifth* column shows the amount of metal volatilized by each spark in fractions of a grain troy.

TABLE A.

	1		2	3	4	5
*Upper Pole	Gold	16·6	15·9	·7	1-4286	1-277000
Lower "	"	16·7	16	·7	"	"
Upper "	Copper	18·5	18·4	·1	1-30000	1-1940000
Lower "	"	"	"	·1	"	"
Upper "	Gold Ingot,	24	23·4	·6	1-5000	1-324000
Lower "	" "	"	"	·6	"	"
Upper "	Tin	20	19·6	·4	1-7500	1-486000
Lower "	"	"	19·4	·6	1-5000	1-324000
Upper "	Silver	24·8	24·6	·2	1-15000	1-976000
Lower "	"	25·1	25	·1	1-30000	1-1940000
†Average.	Lead	91·6	90	1·6	1-1870	1-121000

TABLE B.

Upper.	Gold	20·5	20	·5	1-6000	1-388000
Lower.	Copper	10	9·9	·1	1-30000	1-1940000
Upper.	Gold Ingot	21	20·4	·6	1-5000	1-324000
Lower.	Copper	20·2	20	·2	1-15000	1-976000
Upper.	Silver	6	5·8	·2	1-15000	"
Lower.	Tin	20	19·4	·6	1-5000	1-324000
‡Upper.	Nickel	12	11·95	.05	1-60000	1-3880000
Lower.	"	12	11·9	·1	1-30000	1-1940000

*The upper pole usually formed the positive electrode.

†The average of Lead is given because the results varied in different experiments.

‡The *minimum* of metallic Nickel producing a spectrum according to Cappel's tables is one six hundredth of a milligramme.

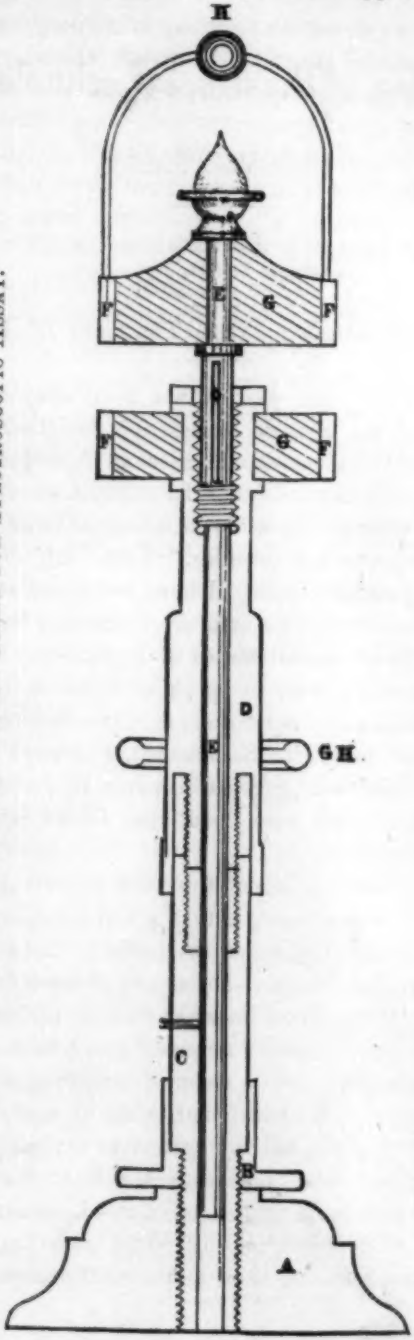


FIG. 4. ADJUSTABLE ROTARY STAND FOR SPECTROSCOPIC ASSAY.

Chemistry, Physics, Technology, etc.

MECHANICAL SCIENCE.

An Address delivered before the Mechanical Section of the British Association at its meeting in Belfast, Sept., 1874.

By Professor James Thomson, LL.D.

For a number of years past it has been customary in this and other sections of the British Association for the Advancement of Science, that the President should give an introductory address at the opening of each new session. In compliance with that usage, I propose now to offer to you a few brief remarks on various subjects of mechanical science and practice. These subjects have not been chosen on any systematic plan. I have not aimed at bringing under review the whole or any large number of the most important subjects at present worthy of special notice in engineering or in mechanics generally. I intend merely to speak of a few matters which have happened to come under my notice, or have engaged my attention, and which appear to me to be interesting through their novelty or through their important progress in recent times, or to merit attention as subjects in which amendment and future progress are to be desired.

In railway engineering, one of the most important topics for consideration, as it appears to me, is that which relates to the abatement of dangers in the conducting of the traffic. The traffic of many of our old railways has become enormously increased in recent years. With the construction of new lines the number of junctions, stations, and sidings has been greatly increased; and each of these entails some attendant dangers. As a natural consequence of the increased traffic on old railways, the additional traffic on new lines, and the increased complexity of the railway system as a whole, there have been during recent years more numerous accidents than in the earlier times of railways. It is to be recollected, however, that with a greater number of people traveling daily, more numerous accidents might be expected, and that their increased frequency, on the whole,

does not necessarily indicate increased danger to the individual traveler. Referring to the statistics of railway accidents published by the Board of Trade in Capt. Tyler's Report for the year 1873, I find for various periods during the last twenty-seven years, throughout the United Kingdom, the proportion of passengers killed from all causes beyond their own control, to the number of passengers carried, to have been, in round numbers:—

Proportion of number killed to number carried:

In the three years 1847, 1848, and 1849, . .	1 in	4,782,000
In the four years, 1856, '57, '58, and '59, .	1 in	8,708,000
In the four years, 1866, '67, '68, and '69, .	1 in	12,941,000
In the three years, 1870, '71, and '72, . .	1 in	11,124,000
And in the single year 1873, ...	1 in	11,381,000

It is thus gratifying to observe, that in spite of the increased risks naturally tending to arise through the increased and more crowded traffic and the more complicated connections of lines, the danger to the individual traveler is now less than half what it was twenty-six years ago; at least this result is indicated, in so far as we can judge, from the statistics of deaths of passengers from causes beyond their own control. That the conducting of the traffic of railways still involves hazards far from inconsiderable, and that we have much to wish for towards abatement of dangers of numerous kinds, is proved by the fact that during the single year 1873 there have been killed of the officers and servants of the railway companies in the United Kingdom, 1 out of every 323; so that, at this rate, extended through a period of, for example, 20 years' service, there would be 1 out of every 16 of the officers and servants killed.

These deaths of officers and servants are not to be supposed to be caused in any large proportions by collisions, and by other accidents to trains in rapid motion.

The great majority of them arise in shunting and other operations at stations and along the lines, and occur in numerous ways not beyond the control of the individuals themselves. In respect to the passengers, too, it ought to be known and distinctly recollected, that although collisions and other violent accidents to trains in rapid motion, together with other accidents beyond the control of the individuals, usually cause by far the deepest impression on the public mind; yet the number of these fatal accidents is small in comparison with others arising to passengers from causes more or less within

their own control. For instance it may be noticed that in last year, the year 1873, while the deaths of passengers arising from all causes beyond their own control, in the United Kingdom, were only 40 in number, there were four times as many killed, namely, 160, in other ways; and of these there were as many as 62 killed in the simple way of their falling between carriages and platforms.

In respect to the conducting of the traffic of the trains in motion, it appears to me, on the whole, than when we consider the vast complexity of the operations involved in working many of our ramified and crowded railways, and when we consider the indefinitely numerous things which must individually be in proper order for their duty, and must be properly worked in due harmony by men far away from one another, some stationed on the land, and others rushing along on the engines or trains, the wonder is, not that we should have numerous accidents, but that accidents should not be of far more frequent occurrence. There can be no doubt, however, but that of the accidents which do occur, many arise from causes of kinds more or less preventible according to the greater or less degree in which due precautions may be adopted.

Gradually, during a period of 20 or 30 years past, a very fine system of watching, signaling, and otherwise arranging for the safety of trains, has been contrived and very generally introduced along our principal lines of railway. In saying this I allude chiefly to the block system of working railways, with the aid of telegraphic signals and interlocking mechanisms for the working of the points and signals.

In former times it was customary to allow a certain number of minutes to elapse after a train passed any station, or junction, or level crossing, or other point where a servant of the company was stationed, before the succeeding train was allowed to pass the same place. Thus, at numerous points along the line a time interval was preserved between successive trains. It was quite possible, however, that the foremost of the two trains, after passing any of these places where the signals were given, might become disabled, or might otherwise be made to go slowly, and that the following train might overtake it, and come into violent collision with it from behind. In order to provide against the occurrence of such accidents, a system was introduced called the *Block System;* and its main principle consists in dividing the line into suitable lengths, each of which is called a *block section*, and allowing no engine or train to enter a block section

until the previous engine or train has quitted that portion of the line. In this way a space interval of at least the length of a block section is preserved between the two trains at the moment of the later train's passing each place for signaling, and the risk of this space interval becoming dangerously small by negligence or other accidental circumstances, as the later train approaches the next place for signaling, is almost entirely avoided.

Further, at each signaling station, the various levers or handles for working the points, and those for working the semaphore signals for guiding the engine-drivers, instead of being, as was formerly the case, scattered about in various situations adjacent to the signaling station, and worked often, some by one man and some by another, without sufficient mutual understanding and without due harmony of action, are now usually all brought together into one apartment called the signal cabin. This cabin, like a watch-tower, is usually elevated considerably above the ground, and is formed with ample windows or glass sides, so as to afford good views of the railway to the man who works the levers for the semaphores and points, and who transmits, by electricity, signals to the next cabins on both sides of his own, and, when necessary, to other stations along the line of railway.

The interlocking of the mechanisms for working the points and for working the semaphores which, by the signals they show, control the engine-drivers, consists in having the levers by which the pointsman works these points and signals, so connected that the man in charge cannot, or scarcely can, put one into a position that would endanger a train, without his having previously the necessary danger signal or signals standing so as to warn the engine-driver against approaching too near to the place of danger.

The latest important step in the development and application of the block system is one which has just now been made in Scotland, on the Caledonian Railway. Before explaining its principle, I have first to mention that a semaphore arm raised to the horizontal position is the established danger-signal, or signal for debarring an engine-driver from going past the place where the signal is given. Now, the ordinary practice has been, and still is, to keep the semaphore arm down from that level position, and so to leave the line open for trains to pass, except when the line is blocked by a train or other source of danger on the block section in front of that semaphore, and only to raise the semaphore arm exceptionally as a signal of danger in front.

The new change, or improvement, now made on the Caledonian Railway consists mainly in arranging that along a line of railway the semaphore arms are to be regularly and ordinarily kept up in the horizontal position for prohibiting the passage of any train, and that each is only to be put down when an approaching train is, by an electric signal from the cabin behind, announced to the man in charge of that semaphore, as having entered on the block section behind, and when, further, that man has, by an electrical signal sent forward to the next cabin in advance, inquired whether the section in advance of his own cabin is clear, and has received in return an electrical signal meaning "*The line is clear: you may put down your debarring signal, and let the train pass your cabin.*" The main effect of this is, that along a line of railway the signals are to be regularly and ordinarily standing up in the debarring position against allowing any train to pass; but that just as each train approaches, and usually before it has come in sight, they go down almost as if by magic, and so open the way in front of the train, if the line is ascertained to be duly safe in front; and that immediately on the passage of the train they go up again, and by remaining up keep the road closed against any engine or train whose approach has not been duly announced in advance so as to be known at the first and second cabins in front of it, and kept closed, unless the entire block section between those two cabins is known to have been left clear by the last preceding engine or train having quitted it; and is sufficiently presumed not to have met with any other obstruction, by shunting of carriages or wagons, or by accident, or in any other way.

This new arrangement, which appears to be very important improvement, has already been brought into action with success on several sections of the Caledonian Railway; and it is being extended as rapidly as possible on the lines of the Caledonian Company, where the ordinary mode of working the block system has hitherto been adopted.

The mechanisms and arrangements I have now briefly mentioned are only a portion of the numerous contrivances in use for abatement of danger in railway traffic. It is to be understood that by no mechanisms whatever can perfect immunity from accidents be expected. The mechanisms are liable to break or to go wrong. They must be worked by men, and the men are liable to make mistakes or failures. We shall continue to have accidents; but, if we cannot do away with

every danger, that is no reason why we should not abate as many dangers as we can.

Within the past twenty years very remarkable progress has been made in steam navigation generally, and more especially, I would say, in oceanic steam navigation. In this we meet with the realization of great practical results from the combination of improved mechanical appliances, and of physical processes depending on a more advanced knowledge of thermo-dynamic science.

The progress in oceanic steam navigation is due mainly to the introduction jointly of the screw propeller, the compound engine, steam jacketing of the cylinders, superheated steam, and the surface-condenser.

The screw propeller, in its original struggle for existence, when it came into competition with its more fully developed rival, the paddle-wheel, met with favoring circumstances in the want then strongly felt of means suitable for giving a small auxiliary steam-power to ships arranged for being chiefly propelled by sails. For the accomplishment of this end the paddle-wheel was ill suited; and so the screw propeller got a good beginning for use on long oceanic voyages. Afterwards, in the course of years, there followed a long series of new inventions and improved designs in the adaptation of the steam-engine for working advantageously with the new propeller; and it has resulted that now, instead of the screw being used as an auxiliary to the sails, the sails are more commonly provided as auxiliaries to the screw. For long oceanic voyages it became very important or essential to get better economy in the consumption of fuel. In order to economize fuel, high-pressure steam, with a high degree of expansion and with condensation, was necessary. This led to the practical adaptation for the propulsion of vessels of the compound engine, an old invention which originated with Hornblower in the latter part of the last century, and was afterwards further developed by Wolff. The high degrees of expansion could not be advantageously used in cylinders heated only by the ordinary supply of steam admitted to them for driving the piston; and more especially when that steam was boiled off directly from water without the introduction of additional heat to it after its evaporation. The knowledge of this, which was derived through important advances made in thermo-dynamic science, led to the introduction into ordinary use in steam navigation of steam-jacketed cylinders, and to the ordinary use also of superheated steam.

With increased efforts towards economy of space in the hold of the ship, which became the more essential when very long voyages were to be undertaken, and with the new requirement of greatly increased pressure in the steam, the old marine boilers, with their flues of riveted plates, were superseded by tubular boilers more compact in their dimensions and better adapted for resisting the high pressure of the steam. In connection with these various changes the old difficulty of the growth of stony incrustations in the boilers became aggravated rather than in any way diminished. As the only available remedy for this, there ensued the practical development and the very general introduction of the previously known but scarcely at all used principle of surface condensation instead of condensation by injection. A supply of distilled water from the condenser is thus maintained for feeding the boilers, and incrustations are avoided. The consumption of coal is often found now to be reduced to about 2 lbs. per indicated horse-power per hour, from having been 4 or 5 lbs. in good engines in times previous to about twenty years ago.

Before the times of ocean telegraph cables, very little had been done in deep-sea sounding; but when the laying of ocean cables came first to be contemplated, and when it came afterwards to be realized, the obtaining of numerous soundings became a matter of essential practical importance. In the ordinary practice of deep-sea sounding, as carried on, both before and since the times of ocean telegraph cables, until a year or two ago, a hempen rope or cord was used as the sounding line, and a very heavy sinker, usually weighing from two to four hundred-weight, was required to draw down the hempen line with sufficient speed, because the frictional resistance of the water to that large and rough line moving at any suitable speed was very great. The sinker could not be brought up again from great depths; and arrangements were provided, by means of a kind of trigger apparatus, so that when the bottom was reached the sinker was detached from the line and was left lying lost on the bottom; the line being drawn up without the sinker, but with only a tube, of no great weight, adapted for receiving and carrying away a specimen of the bottom. For the operation of drawing up the hempen line with this tube attached, steam power has been ordinarily used, and practically must be regarded as necessary.

(To be continued.)

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